First lecture

Introduction for Plant Physiology

It is a branch of botany and is concerned with the study of various biological activities and their interdependence with each other with the relationship of these activities to outer surroundings that surround plant. This science is associated with other plant sciences such as Plant Anatomy, Plant Genetics, Plant Taxonomy , Plant Adaptation for Living in different environments. This science studies Biochemical reaction to learn the organs functions and how to help these functions in the growth processes and flowers, fruits and seeds formation.

What is Plant Physiology? Plant physiology is the study of the functions and vital processes occurring in plants including metabolism, water relations, mineral nutrition, development, movement, irritability (response to the environment), growth, and transport processes.

Solutions

All living matter depends on water . Protoplasm is dissolved or dispersed in water , nearly all the materials in the cell are transported in water and almost all biological reactions take place in aqueous solution . The peculiar physical ,chemical and electrical properties of solution and dispersion of material in water provide the basis for the chemistry and physics of living material. It is important to understand clearly the properties of solution.

A solution consist of at least two components

1- solute (ions or molecules)

2- solvent (liquid , gas or solid)

The important solvent in all living organism is the liquid.

Solution can divide in to four different types depended on the state of solute and solvent

1- True solution

2- Colloidal system

3- Suspension solution

4- Emulsion solution

True Solution : is a homogeneous mixture has the same uniform appearance and composition throughout, where one substance (solute) is dissolved in another substance (solvent). Substance in a true solution exists in molecular or ionized form.

General properties of liquid solutions

- True solution is a mixture of two or more substances in a single phase.

- True solutions have particles which are the size of atoms or molecules less than 1 nm (0.001 µm).

- Liquid solutions are clear and transparent with no visible particles of solute.

- The particle size of the solute (molecules, atoms, or ions) is about the same as that of the solvent, and solvent and solute pass directly through the filter paper.

- Solute particles will not settle out after a time.

Example: mixing the NaCl salt into the water results in breaks the salt into sodium (Na^+) and chlorine (Cl^-) ions within the water solvent

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Colloidal Solution: is a type of mixture intermediate between a homogeneous mixture (true solution) and a heterogeneous mixture (suspension) with properties also intermediate between the two. - The dispersed-phase particles have a diameter of between approximately 0.001 and 0.1 µm. - Generally cannot be filtered, or settled out in an easy manner. Figure 3.1.Suspension , colloid and true solution mixtures The scientist Graham gave terms sol and gel to denote the two different states of the colloidal systems. A sol has a high degree of fluidity and appears like solutions while the gel is almost solid, but has more or less an elastic system.

Suspension solution: is a heterogeneous mixture between two or more substances, where the particles are typically large enough to be seen by the naked eye. - The dispersed-phase particles have a diameter of approximately more than 100 nanometers (0.1 μm) in diameter. - Generally can be filtered, and settled out in an easy manner. - An example is mixed of sand and water.

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Table: Difference between True Solution, Suspension and Colloidal Solution

Property	**True Solution**	**Colloidal Solutions**	**Suspension**
Size of the particles	< 1nm	1– 1000nm	>1000nm
Nature	Homogeneous	Heterogeneous	Heterogeneous
Filterability(Diffusion through parchment paper)	Particles of true Solution diffuse rapidly through filter paper as well as parchment paper.	Colloidal particles pass through filter paper but not through parchment paper.	Suspension particles do not pass through filter paper and parchment paper.
Visibility	Particles of True Solution are not visible to naked eye.	Colloidal particles are not seen to naked eye but can be studied through ultra microscope.	Suspension particles are big enough to be seen by naked eye.
Tyndall effect	True Solution does	Colloids shows	Suspension may or

not show Tyndall effect.	Tyndall effect.	may not show Tyndall effect.

Emulsion solution: Emulsions are composed of two liquids that usually do not mix together (immiscible). The particles of one liquid are dispersed throughout the other liquid. The particles are more than 100 nanometers (0.1 µm) in diameter. Emulsions like suspensions, are unstable, the two components of an emulsion rapidly separate from one another.

Also solution divide to four types dependence on concentration

1- Molar solution

2- Molal solution

3- Normal solution

4- Percentage solution

Buffer solution. A buffer is an aqueous solution containing a weak acid and its conjugate base or a weak base and its conjugate acid. A buffer's pH changes very little when a small amount of strong acid or base is added to it. It is used to prevent any change in the pH of a solution

A mixture of the weak acid and its salt or a weak base and its salt , will resist any change in hydrogen ion concentration when small amount of a strong acid or base are added to it. Example acetic acid with sodium acetate .

Electrolytic and Non- electrolytic solutions

Electrolytes are substance that can conduct an electric current when they are dissolved in water . The passage of an electric current through an aqueous solution of an electrolyte results in the decomposition of electrolyte , this process is called electrolysis

Example : if an electric current is allowed to pass through an aqueous solution of hydrochloric acid , hydrogen gas will be released at the cathode and chlorine gas at the anode. Acids, bases and salts are electrolytes ,their ability to conduct electricity results from the fact that electrically charged ions are formed when they are dissolved in water. Sugars and alcohols do not undergo ionization when dissolved in water and ,therefore ,are termed non-electrolytes.

Amphoteric compounds

Water can act either as weak acid or a weak base ,that is , it can either donate or accept a proton . Amino acids ,components of the protein molecule, are also good examples of components that can act as weak acid or weak base i.e Compounds that can act both as an acid and as a base are said to be Amophoteric **.**

The living cell and the colloidal state

The protoplasm of the cell is not a true solution. Although there are many materials that are dissolved, much of the particulate phase of the protoplasm is colloidal in nature. Indeed, the protoplasm is usually referred to as a colloidal complex and exhibits many of the properties

Attributed to colloidal system.

Colloidal systems

such as solutions of certain proteins, and liquid preparation of vegetable gums such as gum Arabic.

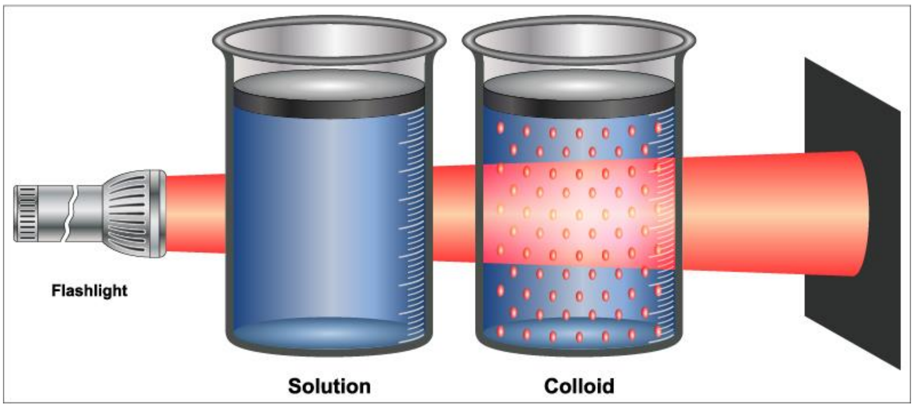
Classification of sol colloids based on nature of interaction between dispersed phase and dispersion medium

1. Lyophilic sols: The term lyophilic means liquid-loving (solvent loving). When water is used as the dispersion medium, such colloids are termed as hydrophilic colloid. Gelatin, albumin, starch are some common examples of lyophilic colloids.

2. Lyophobic sols: The term lyophobic means liquid-hating (solvent-hating). The substances which do not attractive to the dispersion medium are called hydrophobic colloids. The examples of hydrophobic colloids are the metals and their sulfides and hydroxides

Properties of colloidal system

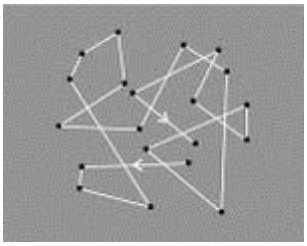
1- Tyndall phenomenon: is the scattering of light by colloidal particles present in a colloidal solution.This phenomenon cannot be seen in the case of pure water or a true solution. This phenomenon is known as the Tyndall effect after is original discover, John Tyndall.



2- Brownian movement: Robert Brown (1927) an English Botanist, observed that the pollen grains in aqueous suspensions were in constant motion. The continuous zigzag movement of the colloidal particles in the dispersion medium in a colloidal solution caused by collisions with molecules of the surrounding medium.

Cause of Phenomenon:

The Brownian movement is due to the bombardment of colloidal particles by molecules of dispersion medium. The intensity of motion depends upon the size of the particles and the viscosity of the dispersion medium. The smaller the particles and the less viscous the dispersion medium, the more vigorous is the Brownian movement and vice versa

. 

2-Adsorption: The ability of molecules or ions to adhere to the surface of certain solid or liquids is known as adsorption. Since it is a surface phenomenon, the capacity for adsorption is dependent up on the amount of surface exposed as well as the chemical nature of the constituents involved. Most of the important functions of colloidal systems found in the living cell are dependent upon their immense adsorptive capacity.

3-Electrical properties: Colloidal particles generally carry an electric charge .The charge may be either positive or negative ,but in a given colloidal system it is same for all particles. For example ,the particles of a ferric hydroxide colloidal suspension all carry a positive charge ; the particles of a colloidal suspension of arsenic sulfide all carry a negative charge .

The charges found on colloidal particles result from the adsorption of free ions the dispersion medium. The preferential adsorption of positive ions by a colloidal particle will give it a positive charge , whereas the preferential adsorption of negative ions results in a negatively charged colloidal particle. In the ferric hydroxide colloidal suspension of all the particles have a positive charge because the ferric ion ,released in the ionization of Fe^{+3}n,is preferentially asorbed . The free chlorine ions (Cl^-) are attracted to the positive charge on the particles , and they also accumulate secondarily around the particles forming what is known as an electrical double layer .In the arsenic sulfide system , sulfide ions(S^{-2}) are prefentially adsorbed by the arsenic sulfide particles .Hydrogen ions , released in the ionization of H_2S, are secondarily adsorbed by the negatively charged particles

The fact that the colloidal particles carry an electric charge and that all the particles of any one suspension carry the same charge is mainly responsible for the stability of colloidal suspensions .Units of like charge repel each other. If it were not for this, the colloidal particles would collide and aggregate and eventually precipitate out of suspension.

4-Precipitation: Removal of the electric double layer will cause the dispersed particles of a colloidal suspension to colloide, aggregate and finally to precipitate out of suspension .This may be accomplished by the addition of an electrolyte for example the addition of HCl to a colloidal suspension of arsenic sulfide will cause precipitation .Hydrogen ion concentration is increased by the addition of HCl to the extent that it causes H_2S to form ($2H^+ + S^{-2} === H_2S$).The removal of the negative charges on the sulfide ions causes the particles to be neutralization .The extent to which an ion will cause precipitation when added to a colloidal suspension depends on its valence. The monovalent sodium ion, for example ,is less efficient than the divalent barium , which in turn is much less efficient than the trivalent ion.

Sometimes a colloid can be protected from precipitation by the another colloid . Apparently ,one colloid forms a protective film around the particles of the other colloid, Gelatin and gum Arabic are the two colloids most widely used in this capacity .For example the colloidal dispersion of silver halides on photographic plates is protected by the gelatin on these plate.

5-Filtration: Although the dispersed phase can not be separated from the dispersion medium with ordinary filter paper ,colloidal particles can be separated from the dispersion medium with ultra filters .Ultra filters composed of biologically inert cellulose esters (Millipore filters) have been constructed with pore sizes ranging from 10 m micron to 5 microm since colloidal particles range in size from 1 to 200 m microm ,it is easy to see that separation of the two phases of a colloidal suspension could be accomplished in most cases by the use of these filters. The components of true solutions, however ,canot be separated in this manner.

6- Viscosity: The viscosity of a fluid is its resistance to flow. While the viscosity of hydrophilic sols is almost similar to that of water, the viscosity of hydrophobic sols is usually greater than that of its dispersion medium.

The Protoplasm as a Colloidal System The protoplasm of the cell is not a true solution. Although many substances are truly dissolved, much of the particulate phase of the protoplasm is colloidal in nature. The protoplasm is believed to be a complex colloidal system of many phases, and its behavior is mostly of a hydrophilic sol. In the protoplasm the continuous phase is a watery solution of salts and the discontinuous phase is an emulsion of organic compounds, e.g., fatty acids and proteins.

Gel

There are two types of colloidal systems

1- Elastic type

2- Non –elastic type

The gels have certain properties which can exchange from one type to another

Elastic type: when heated this gel we fined the gel converted to sol by process called gelation ,but when the sol converted to gel ,the process called solation

Gelation Solation

Gel-------------- Sol Sol------------- Gel

However by lowering temperature sols go back to gel .When gels change to sols by heating, this sols have the same physical properties of the gel.

Non- elastic type: when change gel to sol by heating

Sol can not go bake to gel .Applying heat in to non-elastic type ,the physical properties of sol have the certain difference at gel colloidal system .there are two important properties of gel.

1- Hystresis

2- Thixotropy

Hystresis means that the ability of gel to remember the quantity of water absorbed .for example percentage of these gel are

10%, 20%, 30%, 40% if we dry all these gels by of an oven and allowing them by water again each of these gels take amount of water depend on its actual reaction i.e. each of these gel absorbed water according to the first concentration .This phenomenon is important in biological system define that certain plant under extreme in environmental condition ,drying season or environmental effecting in the plant so that if colloidal system dose not remember the actual contain they are contain distribution of the actual contain in cytoplasm ,so that this phenomeis very important in remaining the cell in good condition.

Thixotropy means that the changing in appearance of only substance by shaking , when converted gel to sol , gel without lossing its physical properties. When sol remain stable can be change to gel.

shaking stable

Gel----------- Sol Sol ----------- Gel

Plant water relationship

Properties of water

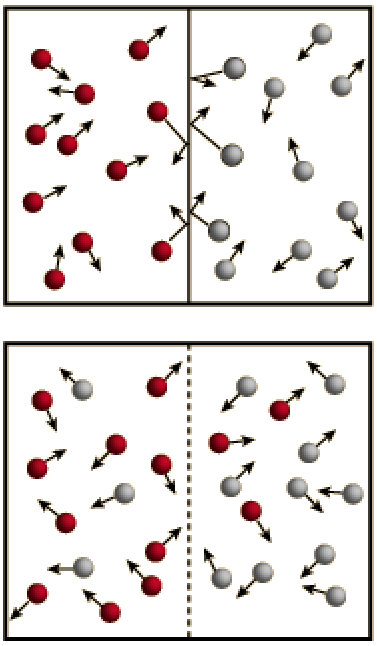
Water is a compound of unique properties, its qualitative heat is high which enables living tissues to absorb or lost large amounts of heat without a significant changes in temperature. It has a relatively high evaporation heat causing the loss of large amounts of energy under favorable conditions causing cooling process. Water is less dense in its solid state than it is in liquid state, and therefor ice floats above the surface of the water. This fact is important for aquatic life. Water molecules are connected to each other (cohesion)and adhere to different surfaces(bounding). Both cohesion and bonding together to raise water inside the plant body. The above- mentioned water properties due to the structure of the water molecule from two covalent hydrogen atoms on one side with the oxygen atom. The average angle of the H-O-H bound is approximately 105^0 .

In addition water is universal solvent for many substances ,salt, sugar and inorganic anions. The medium in which all biochemical reactions takes place is that water. Water is absorbed first and then represents in photosynthetic process, so water can be counted as a nutrient like other nutrients. Water is also important in plant cell gaps where it exerts pressure on the protoplasm and called turgor pressure which maintains the rigidity of leaves and roots and other parts of the plant.

Diffusion

The net movement of substance from an area of its own high concentration into another area of lesser concentration as a result of the ,translational kinetic motion of molecules, ions ,atoms . Diffusion is the net movement of substance from an area of its own high chemical potential into another area of its lower chemical potential along the concentration gradient.

Diffusion refers to the process by which molecules intermingle as a result of their kinetic energy of random motion. Consider two containers of gas A and B separated by a partition. The molecules of both gases are in constant motion and make numerous collisions with the partition. If the partition is removed as in the lower illustration, the gases will mix because of the random velocities of their molecules. In time a uniform mixture of A and B molecules will be produced in the container.



The tendency toward diffusion is very strong even at room temperature because of the high molecular velocities associated with the thermal energy of the particles.

At that point , the probability of solute molecules passing between the chambers in either direction will be equal and net diffusion will cease

i.e diffusion

Movement of any molecules from the region of higher concentration to region of lower concentration

Bulk flow(mass flow): some water movement in plants through the xylem tissues of plants. Movement of materiales by bulk flow is pressure driven. Bulk flow occurs when an external force ,such as gravity or pressure is applied .As a result ,all of the molecules of the substance move in mass ,Bulk flow is pressure –driven ,diffusion is driven principally by concentration differences.

Diffusion pressure (DP): Pressure exerted by diffusing particles on the diffusing medium is called diffusion pressure. Or the weight of the gas(air) above the surface of the mercury placed in a cap plate is used to push a column of mercury into a glass tube to top to reach the height 760 ml.

Factors affecting diffusion process: There are 3 factors,

(1) Density of diffusing particles. "The rates of diffusion of gasses are inversely proportional to the square roots of their relative densities according to Graham 's law. If we apply this equation to the gasses H2 & O2 we find: $r\,H_2/r\,O_2 = \sqrt{dO_2}/\sqrt{d\,H_2} = \sqrt{16}/\sqrt{1} = 4/1$. The rate of diffusion of Hydrogen is Four times that of Oxygen because the density of oxygen 16 times more hydrogen .

Some gases diffuse differently ,some gases diffuse more rapidly than other depend up on its density e.g. ethylene diffuse more rapidly than oxygen

oxygen diffuse more than nitrogen

(2) Nature of diffusing medium.

Less concentration of media more diffusion takes place .If we have two system(1,2), which they have same gases

System(1) has 100 molecules of medium

System(2) has only 5 molecules

Diffusion takes place in two systems but it is more in second system . In system (1) most of molecules of gas collude with the molecules of media and the kinetic energy of gas molecules is reduced ,it means that molecule has not sufficient kinetic energy , overcome the energy potential line with this result in this diffusion of this gases, but in system (2) the molecules of gas can escape out because they have high kinetic energy and result the rate of diffusion is more than the rate diffusion in system (1).

(3) Temperature. The rate at which a gases will diffuse increase as temperature increases.

Increase temperature will lead an increase in diffusion of gases , it means that increase temperature will leads to an increase kinetic energy of molecules .It means molecules accept energy sufficient to overcome the line (energy between molecules) and became free in system. However when decrease temperature will decrease kinetic energy and diffusion not takes place.

4- Chemical potential gradient

The speed of diffusion increases as the difference in the diffusion pressure slop increases in two regions Therefore the rate of diffusion of certain molecules from one region to another is directly proportional to the diffusion material concentration difference between two these region and inversely with distance between them

Significance of diffusion:

(1) Diffusion of into the leaf through stomata during photosynthesis.

(2) Absorption of water (passive absorption).

(3) Absorption of mineral elements (passive adsorption).

(4) Ripening of fruit.

(5) Conduction of organic solute (translocation)

Imbibition are a physical process mainly concerned with absorption of water .If a living (e.g. seed) or a dead plant (e.g. dry wood) material is kept in water ,it absorbs water and swells, leading to increase in volume (it is adsorption of water). .

These substances (seeds, dry wood etc) are called imbibants. The liquid (water) which is absorbed is termed as imbibed substance and the phenomenon is referred to as imbibitions. Imbibitions may be defined as a physical process in which living or dead plant materials take up water or liquid mainly by adsorption due to the presence of hydrophilic or lyophilic colloids inside them through the sub microscopic capillaries present on their general surface of the body.

In plants imbibitions of water takes place by the constituents of cell wall and protoplasm such as carbohydrates, proteins etc.

Conditions necessary for imbibition

i. The existence of a diffusion pressure gradient between the imbibing and the substance imbibed.

ii. The existence of certain affinity between components of the imbibing and the imbibed substance.

Dry plant materials and seeds posse too much negative water potential. As a result water moves into them, when the plant materials arc placed in water.

The movement of water into plant materials continues till a dynamic equilibrium is attained. An imbibing does not necessarily imbibe all kinds of liquids. For example, dry plant materials immersed in ether do not swell appreciably. However, rubber, a plant product does imbibe ether and swell appreciably if submerged in it. On the other hand rubber will not imbibe water.

This shows there exists some affinity or attractive force between the imbibing (rubber) and the liquid ether a considerable amount of materials such as proteins, carbohydrates etc. occur as hydrophilic colloids inside the cells. They have a strong affinity for water.

Imbibition Pressure : It represents the pressure that an imbibing develops when submerged in water. This pressure can be of tremendous magnitude. This fact becomes clear from the splitting of rock brought about by inserting dry wooden stakes in the cruises of rock and soaking them with water.

Why does rock split because too much imbibition pressure develops due to imbibition. The imbibition pressure also helps in breaking soil profiles by germinating seeds.

Factors affecting the rate of imbibition

1. Temperature:

The rate of imbibition increases with the increase in temperature.

2. Concentration of the Solute:

The presence of solutes in water affects the rate of imbibition, the rate of imbibition is more in pure water than in a solution. Increase in concentration of the solute decreases imbibition. Imbibition totally ceases at a very high concentration of solutes in external solution.

Biological importance of imbibition:

1. Imbibitions play a key role in the initial stage of water absorption by the roots.

2. Imbibitions initiate seed germination.

3. The imbibition force is useful in adhering water to the walls of xylem elements.

4. It helps fruits to retain water.

5. It also plays a major role in young and actively growing tissue

Permeability: Substance is said to be permeable, should allow certain substance to pass through it. This phenomenon is called permeability and the substance is called permeable substance.

Based on permeable property membranes are classified in to following types,

1· Permeable membrane

2· Semi permeable membrane

3· Selectively permeable membrane

4· Impermeable membrane

Permeable membrane: A type of membrane which allow all the substances to pass through it.
e.g.: Cell wall and filter paper.

Semi permeable membrane: A type of membrane which allow only solvent molecule to pass through it e.g.: Cell membrane and parchment paper.

Selectively permeable: Type of membrane which selects certain substance to pass through depending upon the condition of cell e.g.: Nuclear membrane, mitochondrial membrane, chloroplast membrane.

Impermeable membrane: Type of membrane which does not allow any substance to pass through it e.g.: glass wall

General rules of permeability

1- Material permeability increases with increasing solubility in plants, the cell membrane containing the fatty acid ,and the presence of polar groups such as COOH , OH, C=O, NH_2 , $CoNH_2$ and SH in the material leads to a lack of the solubility in lipids, believes that the reason for the low rate of permeability is this polar materials will made hydrogen bonds with water and will be surrounding by aqueous sheath and reduce the speed of permeability and thus implemented slowly .

2- Increasing length of carbon chains causes lack of polarity and increase solubility in lipids and thus easy permeability such as urea slower than ethyl urea.

Urea<Methylurea<Ethylurea<Diethylurea<Triethylurea

3-The nitrogenous compounds and halogen hydrocarbons and their dreivatives are fast soluble in lipids, this quickly implemented.

4-Replace the oxygen atoms by sulfur atoms increases the solubility in fat , causing increasing permeability

Thiourea pass through plasma membrane faster than urea

5-There is a relationship between the rate of permeability and partical size or material passing within certain limits.

$$\text{Permeability rate } \alpha \frac{1}{\text{Particles size}}$$

Factors affecting permeability

1-Temperature: It lead to Increase permeability until reach a certain limit .But increasing temp. then cause membrane damage to the cell .This is called balanced solution . The benefit this solution is to save the plasma membrane from damage caused by single salt.

2-PH: The more pH will affect the ionization of materials ,and the structure of plasma membrane ,then inceasing the permeability.

3- antagonism ions: Prevention ion in less valence by ion with highest valence with same charge ,in solution resulting in mix of these two ions without cause damage to the cell .This is called balanced solution , the benefit this solution is to save the plasma membrane from damage caused by single salt.

4- The presence of toxic substances or narcotic such as ether , chloroform ,dissolve lipids and increasing permeability.

5-The effect of radiation in all its types

6- Physiological activity of cell

OSMOSIS:

The process of movement of solvent from the region of their higher concentration to the region of their lower concentration through semi permeable membrane is called osmosis. **Osmosis** is the spontaneous net movement of solvent molecules through a partially permeable membrane into a region of higher solute concentration, in the direction that tends to equalize the solute concentrations on the two sides. It may also be used to describe a physical process in which any solvent moves, without input of energy, across a semipermeable membrane (permeable to the solvent, but not the solute) separating two solutions of different concentrations. Although osmosis does not require input of energy, it does use kinetic energy and can be made to do work.

The osmotic pressure is defined to be the pressure required to maintain an equilibrium, with no net movement of solvent.

Osmosis is essential in biological systems, as biological membranes are semipermeable. In general, these membranes are impermeable to large and polar molecules, such as ions, proteins, and polysaccharides, while being permeable to non-polar and/or hydrophobic molecules like lipids as well as to small molecules like oxygen, carbon dioxide, nitrogen, nitric oxide, etc. Permeability depends on solubility, charge, or chemistry, as well as solute size.. Osmosis provides the primary means by which water is transported into and out of cells. The turgor pressure of a cell is largely maintained by osmosis, across the cell membrane, between the cell interior and its relatively hypotonic environment.

Osmosis can occur when there is a partially permeable membrane, such as a cell membrane. When a cell is submerged in water, the water molecules pass through the cell membrane from an area of low solute concentration to high solute concentration (e.g. if the cell is submerged in saltwater, water molecules move out; if it is submerged in freshwater, however, water molecules move in); this is called osmosis. The cell membrane is selectively permeable, so only necessary materials are let into the cell and wastes are left out. The word 'osmosis' is particular to the diffusion of *water* molecules into the cell.

When the membrane has a volume of pure water on both sides, water molecules pass in and out in each direction at exactly the same rate; there is no net flow of water through the membrane.

Osmosis can be explained using the concept of thermodynamic free energy: the less concentrated solution contains more free energy, so its solvent molecules will tend to diffuse to a place of lower free energy in order to equalize free energy. Since the semipermeable membrane only allows solvent molecules to pass through it, the result is a net flow of water to the side with the more concentrated solution. Assuming the membrane does not break, this net flow will slow and finally stop as the pressure on the more concentrated side lessens and the movement in each direction becomes equal: this state is called dynamic equilibrium. water enters the roots by osmosis..

Osmosis can also be seen when potato slices are added to a high concentration of salt solution. The water from inside the potato moves to the salt solution, causing the potato to shrink and to lose its 'turgor pressure'. The more concentrated the salt solution, the bigger the difference in size and weight of the potato slice. **Exosmosis:** Movement of water molecules out of a cell when the cell is placed in hypertonic solution.

Endosmosis: Movement of water molecules into the cell when the cell is placed in hypotonic solution.

Basic phenomena involved in osmosis:

(1) Plasmolysis

(2) Deplasmolysis

Plasmolysis: It is a phenomenon in which protoplasm loses water content when a cell is placed in hypertonic solution.

Deplasmolysis: It is a phenomenon in which protoplasm regain water content when the cell is placed in hypotonic solution

Plasmolysis: The behavior of the plant cells with regard to water movement depends on the surrounding solution as follows:

- **Isotonic:** If the external solution balances the osmotic pressure of the cytoplasm, it is said to be isotonic.

- **Hypotonic:** If the external solution is more dilute than the cytoplasm, it is hypotonic. Cells swell in hypotonic solutions.

- **Hypertonic:** if the external solution is more concentrated, it is hypertonic. Cells shrink in hypertonic solutions. Plasmolysis occurs when water moves out of the cell and the cell membrane of a plant cell shrinks away from its cell wall. The movement of water occurred across the membrane moving from an area of high water potential (the cell) to an area of lower water potential outside the cell

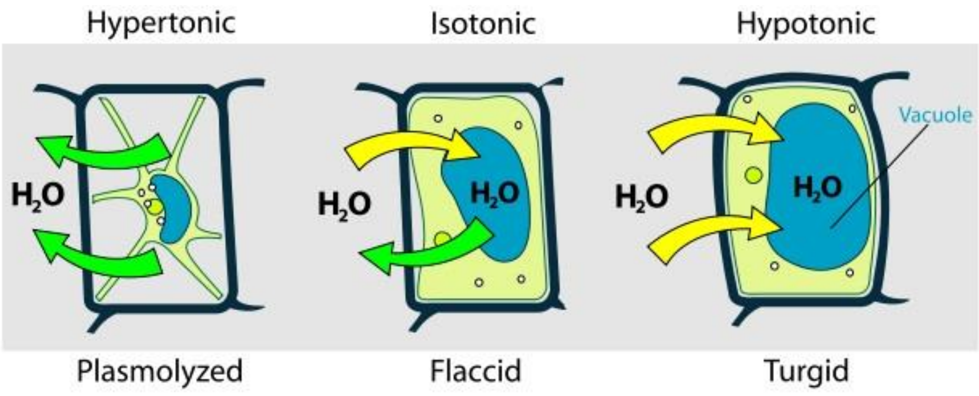


Figure:

Reverse osmosis

Reverse osmosis is a separation process that uses pressure to force a solvent through a semi-permeable membrane that retains the solute on one side and allows the pure solvent to pass to the other side. More formally, it is the process of forcing a solvent from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure.

Conditions in Osmosis:

(i) Turgidity

(ii) Flaccidity

Turgidity: It is a condition of the cell in which volume of the protoplasm increases when a cell is placed in hypotonic solution.

Flaccidity: It is the condition of the cell in which volume of the protoplasm decreases when a cell is placed in hypertonic solution.

Note: (1)Hypertonic solution Exosmosis Plasmolysis Flaccidity.

(2) Hypotonic solution Endosmosis Deplasmolysis Turgidity.

Water potential: The chemical potential voltage difference of a single volume unit between the water model and the free fess water under one temperature

The measure of the relative tendency of water to move from one area to another, and is commonly represented by the Greek letter Ψ.

can be explained by this formula

$\mathbf{\Psi_w = \Psi_s + \Psi_p + \Psi_M}$

Water potential is the 'measure of the ability of water molecules to move freely in solution'. All this means is that is a solution of pure water where there is no solute, all of the water molecules are free to move, so the water potential is high. If a solute is added to the solution, it is attracted to the water molecules, so those water molecules can no longer move freely and the water potential is lower.

$\mathbf{\Psi_s}$: is solute potential . Depending on sum of solute paticales (molecules , ions, amino acids and carbohydrate) .It will decrease potential water and make it negative normal plant leaf $\mathbf{\Psi_s}$= -1 to -2.

$\mathbf{\Psi_p}$: is pressure potential .The effect of wall caused cell turgid this is called turgor potential. The increased part of water potential caused by turgor pressure .There are another pressure called wall potential(equal in value and opposite in direction).It is positive value $\mathbf{\Psi_p} > 0$.

$\mathbf{\Psi_m}$ is the matric potential .The decreasing part of water potential results from colloids absorbing water . Always minus .dried seed $\Psi_m = -100$, in the cell before formation of vacuole .Cell with large vacuole, $\Psi_m > -0.01$ could be canceled .

So water movement between cells in plant depended on $\mathbf{\Psi_w}$.

1. What can we expect to observe if we place a cell inside a solution where the cell's Ψ_w is equal to -0.3 kPa and that of the solution is -0.9 kPa?

A. Water will move out of the cell

B. Water will move into the cell

C. Water will not move into or out of the cell

D. The cell will burst

A is correct. Water moves from an area where water potential is higher, to an area where it is lower. This means that it would move from the cell to the solution outside

2. Simply cell put in solution, its water potential is -0.2 kPa

water moves from the solution to cell

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3. How does water potential vary in relation to solute concentration?

A. It increases the higher the solute concentration

B. It decreases the higher the solute concentration

C. It is not affected by the concentration of solute

D. Solute concentration has an inconsistent effect on it

B is correct. The higher the concentration of solute, the less free the

water molecules are to move, and the lower is Ψ_w.

Q1. If we put a plant cell , has Ψ_s -25 bar and Ψ_p 5 bar in solution has Ψ_s -10 bar .How dose the water will move to equalize.

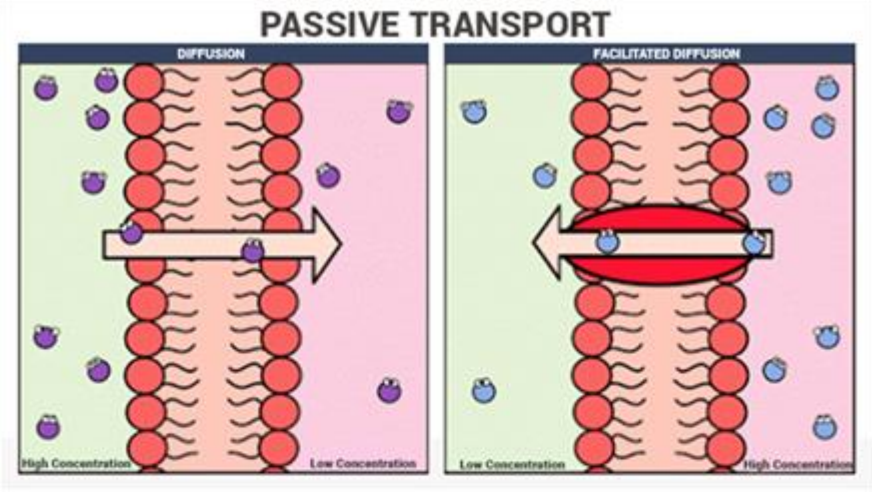
Q2. If we put the same plant cell , in solution has Ψ_s -30 bar .How dose the water will move to equalize.

Dialysis A specialized case of diffusion when solute crosses a semi-permeable membrane. Example – consider a cell containing a sugar dissolved in water. If water (the solvent) moves out of the cell into the surroundings it moves osmotically, if the sugar (solute) moves into the surroundings, it is an example of dialysis.

Ways of solutes entry and transport through the plant cells membranes

1. Passive transport

a-Simple diffusion (Free diffusion): involves the movement of a substance down a concentration gradient between the two compartments separated by a membrane. In simple diffusion substances move through the lipid portion of the membrane. In simple diffusion, gases, such as oxygen and carbon dioxide, can cross membranes, as can lipid soluble substances, such as steroid hormones. This is why oxygen diffuses into the leaf and carbon dioxide diffuse out of the leaf at the same time through the same stomata during the process of respiration. For example, oxygen concentrations are always higher outside than inside the cell and oxygen therefore diffuses down its concentration gradient into the cell; the opposite is true for carbon dioxide.

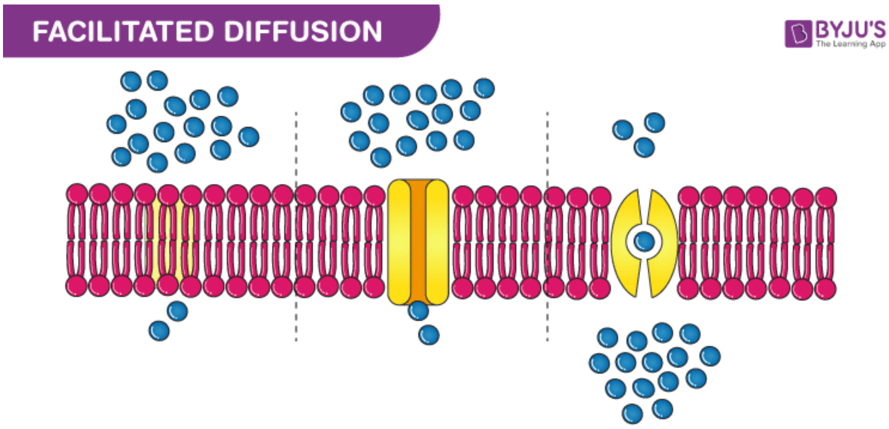


b- Facilitated diffusion: involves the movement of a substance down a concentration gradient between the two compartments separated by a membrane, where specialized membrane proteins called carrier proteins used to allow the transport of the substances. Such proteins allow larger, polar molecules such as sugars , glucose , amino acids , sodium ions and chloride ions to be taken up by cells.

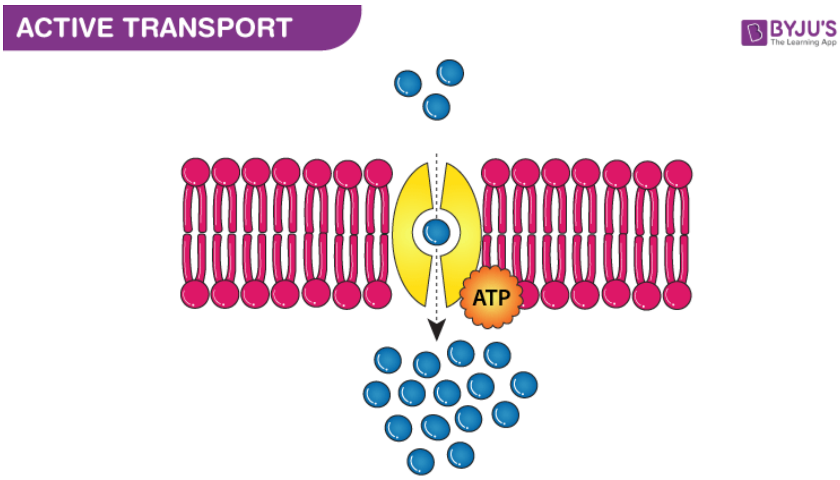
- Smaller substances diffuse faster.

- Substances soluble in lipids diffuse through the membrane faster.

-Substances that have a hydrophilic property, find it difficult to pass through the membrane, their movement has to be facilitated by membrane proteins.



2. Active Transport Active transport uses energy (ATP) to pump molecules against a concentration gradient. Active transport is carried out by membrane-proteins. Carrier proteins bind specific solutes and transfer them across the lipid bilayer.



Relationship between plants and environment

There are three mains way for relationship between plants and environmental from movement and transport:

1- Absorption: from environment to plants
2- Translocation: inter the plant
3- Transpiration: from the plant to environment

Absorption of water and solutes by plants roots

Intimate contact between the surface of root and the soil is essential for effective water absorption. Most of the water that goes into plants by the root hairs that are present in millions at the tips of the roots

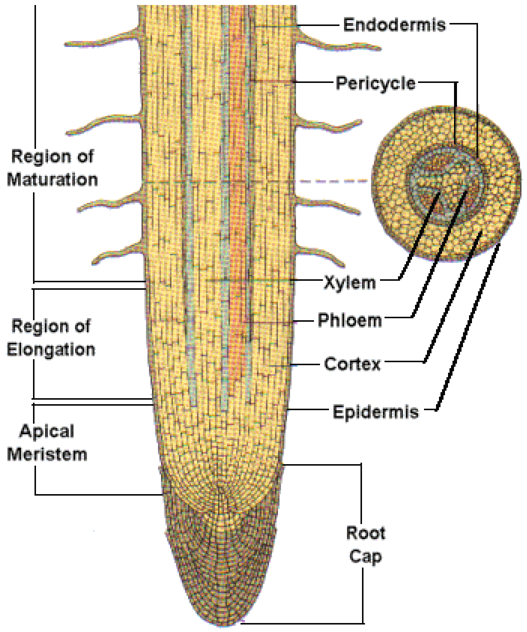


Figure: longitudinal section of root tip

Root hairs are filamentous outgrowths have cells with thin-walled extensions of root epidermal cells that greatly increase the surface area for absorption of ions and water from the soil **Figure** (**2**).

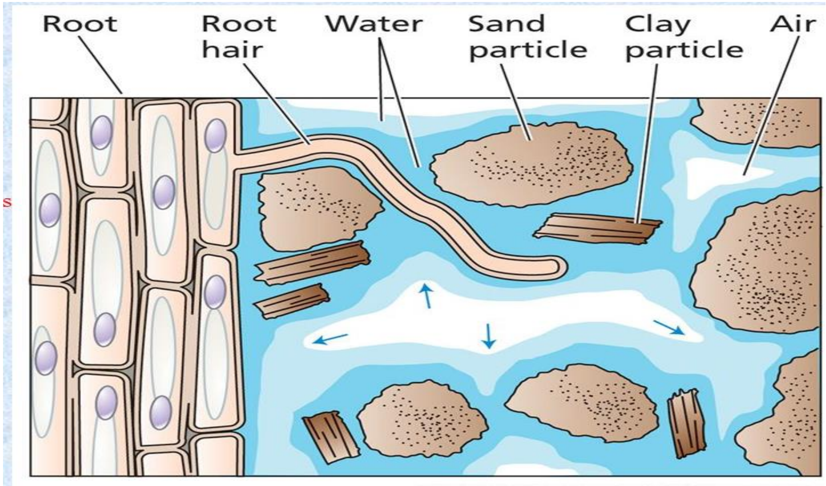


Figure (2): Root hairs intimate contact with soil particles

The intimate contact between the soil and the root surface is easily decrease when the soil is disturbed, and for this reason that newly transplanted seedlings and plants need to be protected from water loss for the first few days after transplantation.

There are three pathways through which water can flow:

1- **The apoplast**
2- **The symplast**
3- **The transmembrane pathway (vacuolar pathway)**

The apoplast: is movement of water and solute through the intercellular spaces at the cells walls (Does not involve crossing the cell membrane) **.**This pathway characterized by :

✓ Less resistance and higher speed of transport.

✓ This movement is dependent on the potential gradient.

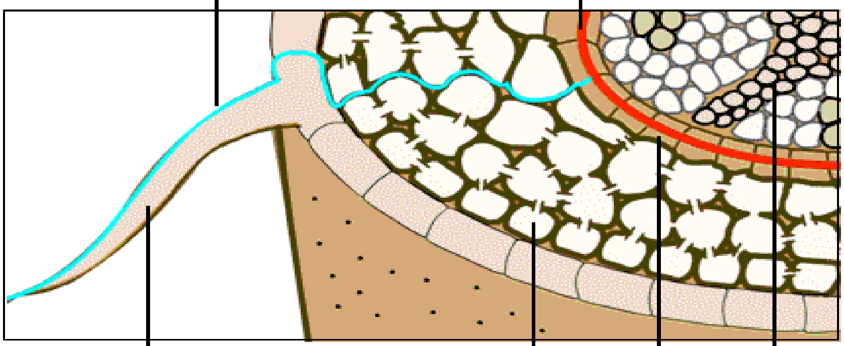


Figure : the apoplast pathway

The symplastic: The protoplasm of the roots cells is connected to each other by plasmodesmata, therefore, water travels across the root cortex by the plasmodesmata **.**Movement of water is depend on the potential gradient

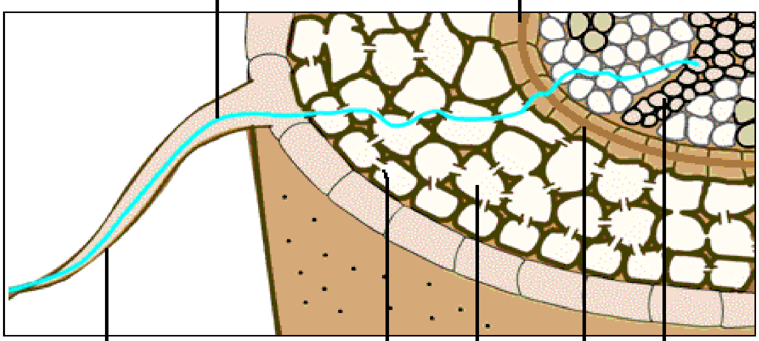


Figure: **The symplastic pathway**

3. Transmembrane pathway (vacuolar pathway)

In the plants roots, when the water movement from soil to the endodermis through apoplastic pathway, through cell wall. The casparian strips in the endodermis (are made-up of wax -like substance suberin) which blocks the water and solute movement. So the water is forced across through cell membranes to the tonoplast of vacuole

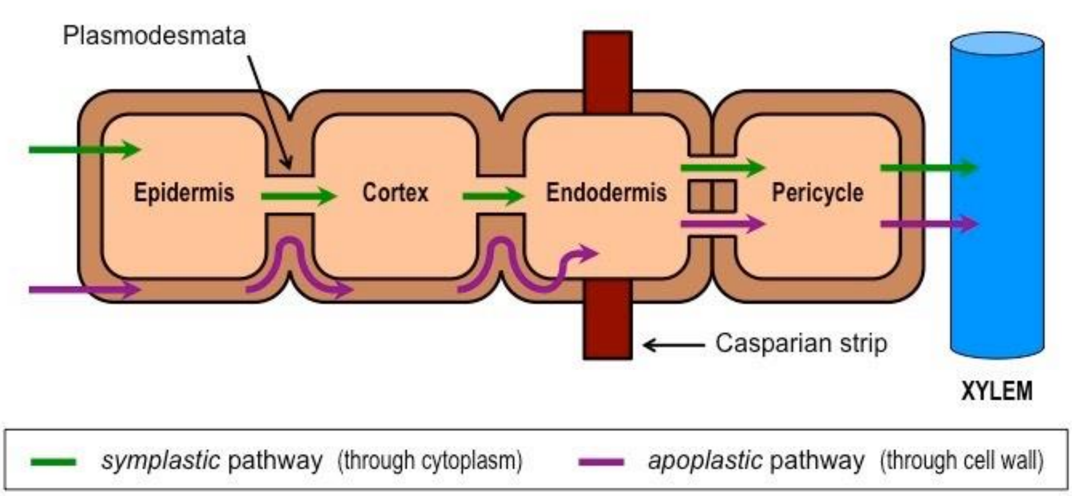


Figure (5). This movement of water through cell membranes is called trans-membrane pathway.

Figure:Diagram showing the apoplastic, symplastic and vacuolar pathways

Factors affecting water absorption by root

Any factor which affects the rate of transpiration will indirectly influence the rate of absorption.

1- Inner factors: Water potential, development degree and respiration of roots.

2- Outer factors: Soil factors, air factors →transpiration →water absorption (indirectly).

The following **soil factors** direct influence on the rate of absorption of water:

1. **Available soil water:** Decrease in the soil water causes decrease in the absorption of water.

2. Concentration of the soil solution: If the solution is highly concentrated due to the presence of salts, its osmotic pressure will be increased which will inhibit the absorption of water.

3. Soil Aeration: Oxygen deficiency decrease absorption of water by the roots because decrease of growth and development of fresh roots and increasing of anaerobic respiration which lead to ethanol accumulation and root toxication.

4. Soil temperature : the maximum absorption of water takes place generally between 20˚C to 30˚C.

Mycorrhizae relation to root : Some plants have additional structures associated with them that help in water and mineral absorption.

- A mycorrhizae is a (symbiotic association) of a fungus with a root system. The fungal filaments form a network around the young root or they penetrate the root cells. The hyphae have a very large surface area that absorb mineral ions and water from the soil from a much larger volume of soil that perhaps a root cannot do.

-The fungus provides minerals and water to the roots, in turn the roots provide sugars and N-containing compounds to the mycorrhizae.

-Some plants have an (obligate association) with the mycorrhizae. For example, Pinus sp. seeds cannot germinate and establish without the presence of mycorrhizae.

Water and minerals transport in plant(Translocation)

Xylem : is associated with translocation of mainly water, mineral salts, some organic nitrogen and hormones, from roots to the aerial parts of the plants.

Phloem : is associated with translocation of a variety of organic and inorganic solutes, mainly from the leaves to other parts of the plants.

Short distance of transport : It is the transport from root hairs to root vessels by diffusion (concentration gradient), the casparian band blocks water transport through apoplast **.**

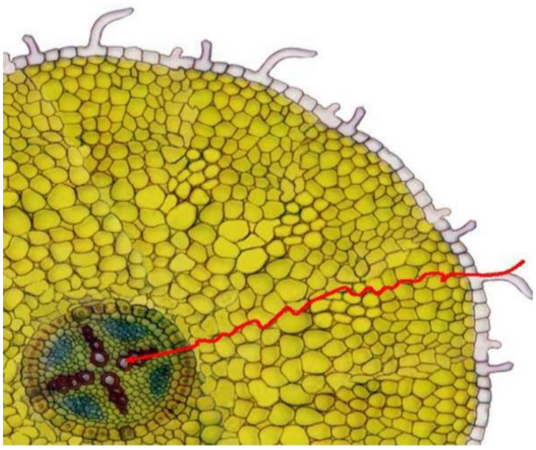


Figure: Short distance transport in plant.

Long distance of transport: Long distance transport of substances within a plant cannot be by diffusion alone, because diffusion is a slow process. Therefore special long distance transport systems (vessels and trachieds in angiosperm and trachieds in gymnosperm) become necessary to move substances across long distances and at a much faster rate **.**

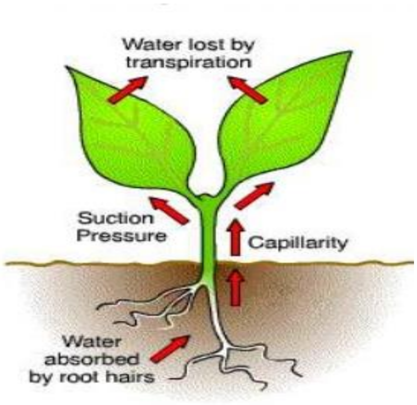


Figure: Short distance transport in plant.

Mass flow: is the movement of substances in bulk or in masse from one point to another as a result of pressure differences between the two points.

Pathway of water transport

Soil → root hair → root cortex parenchyma → root pericycle→ root vessels (tracheids) → stem vessels (tracheids) →petiole vessels (tracheids) → leaf vessels and tracheids→ mesophyll cells → mesophyll cell space →substomatal space → stomata → atmosphere.

Translocation: is the bulk movement of substances through the conducting or vascular tissues of plants through xylem and phloem.

Mechanisms (theory) of water and its solute transport:

1-Root pressure theory in bottom:

Is the pressure in the root because of the osmotic property, the root pressure gets at night because of the accumulation of ions in the roots. While the transpiration is slightly in the leaves or does not exist. This accumulation increases the concentration of ions significantly in the cells, leading to more water entering the roots hairs through the osmotic property. Under certain conditions in some plants, the water solution in the xylem is under positive pressure and is believed to be the result of the movement of osmotic water from the soil to the wood cells in the roots. When the balance between the water potential in the soil and the potential of water in the roots xylem is obtained, a slight pressure in the xylem cells is soon transferred to the stem

2-Transpiration pulls theory in top:

The force for water movement is the water potential gradient that exists from soil to air, as follows:

$$\Psi\text{soil} > \Psi\text{root} > \Psi\text{stem} > \Psi\text{leaf} > \Psi\text{air}$$

Because of lower concentration of water vapour in the atmosphere as compared to the substomatal cavity and intercellular spaces, water diffuses into the surrounding air. This creates a „pull‟.

3- Vital theory:

Depend on the present cells in stem which similar to Parenchyma cells found in xylem, the studies showed those cells don't have any effect for water movement.

4- The Cohesion-Adhesion theory for transport of water and minerals in the xylem:

Cohesion: mutual attraction between water molecules.

Adhesion : attraction of water molecules to polar surfaces (such as the surface of tracheary elements).

According to this theory, water is drawn up and out of the plant by the force of transpiration.

- ✓ The vessels and tracheid are hollow at maturity.
- ✓ Various ions and water from soil can be transported up to a small height in stems by root pressure. **Transpiration pull model** is the most acceptable to explain the transport of water.

Measurements reveal that the forces generated by transpiration can create pressures to lift a xylem sized column of water over 130 meters high.

Guttation is the exudation of drops of xylem sap on the tips or edges of leaves of some vascular plants, such as grasses. Guttation is not to be confused with dew, which condenses from the atmosphere onto the plant surface **.**

At night, transpiration usually does not occur because most plants have their stomata closed. When there is a high soil moisture level, water will enter plant roots, because the water potential of the roots is lower than in the soil solution. The water will accumulate in the plant, creating a slight root pressure. The root pressure forces some water to exude through special leaf tip or edge structures, **hydathodes or water glands**, forming drops. Guttation is most noticeable when transpiration is suppressed and the relative humidity is high, such as during the night.

The chemical content of guttation fluid may contain a variety of organic and inorganic compounds, mainly sugars, and potassium.

Figure: Guttation appeared in some plant leaves.

Bleeding: is the process by which plant loses its substances from the wound. Latex and other exudates are collected from the wound caused in the plant body.

Figure: bleeding appeared from plant wound

The Transpiration

Water present in the most vital consist of all plant tissues, so absorb large amounts of water from the soil but only 2-5 % is used by them for metabolic processes while the rest is translocated to the leaves and lost to the environment in the form of water vapour. Most of the excess water is lost from the aerial parts of the plants by the process of **transpiration**.

Transpiration: is the process which water lost in the water vapour form, from the internal tissues of plants, through the aerial parts of the plant.

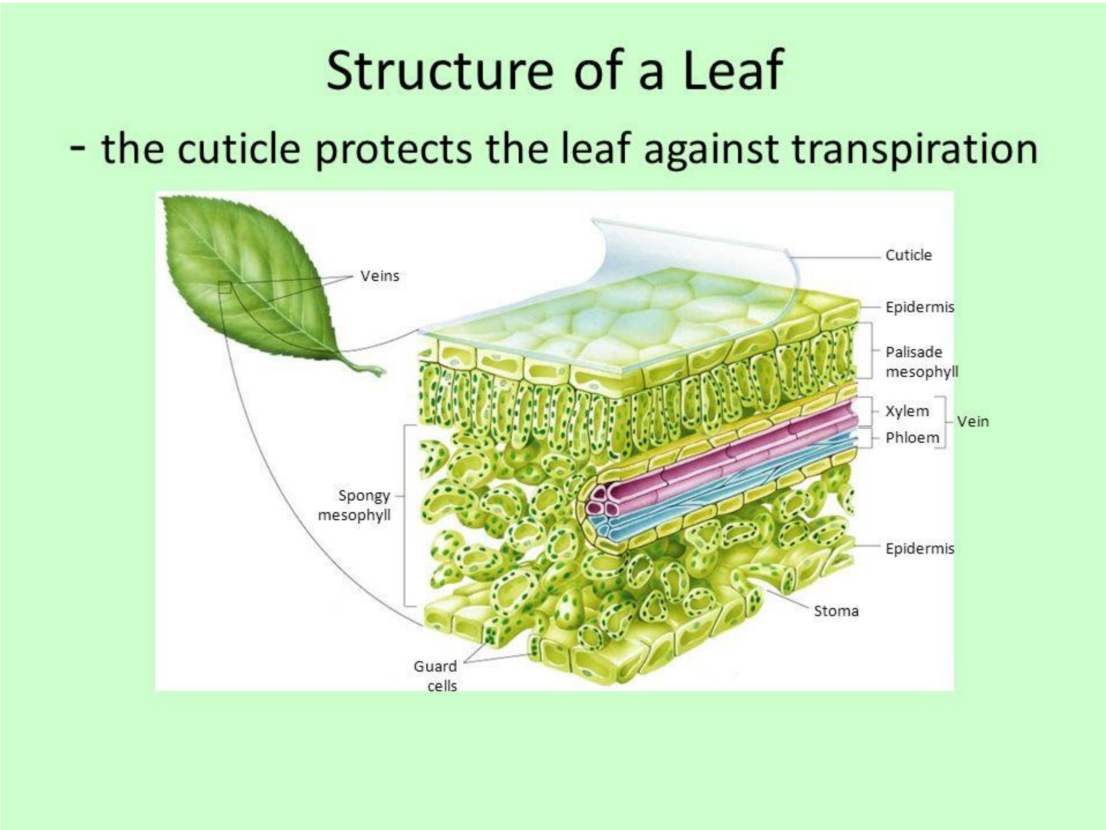
Maximum water loss takes place through the leaves since leaves offer a larger surface area than stems and flowers for evaporation to occur.

when transpiration is low and absorption of water by roots is high, loss of water from leaves in the form of liquid is termed **guttation**.

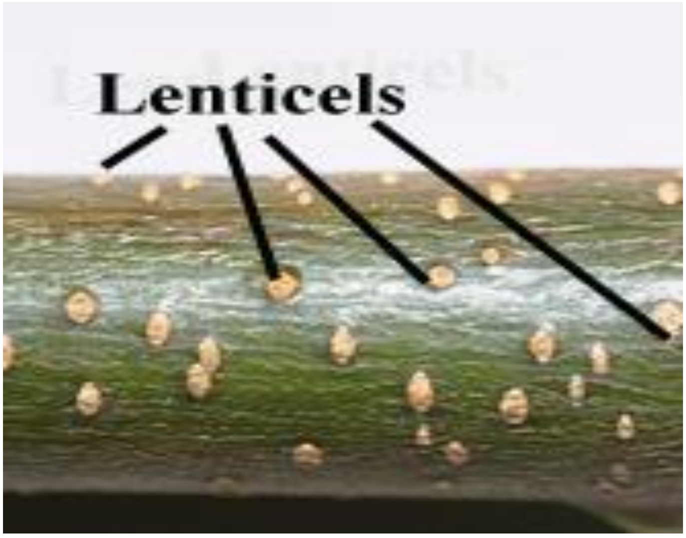
Transpiration is of three types

Plants take up large amounts of water from soil which passes into the internal parenchyma tissues. The water from these cells is constantly evaporating and collecting in the intercellular spaces. This water diffuses out into the atmosphere by one of the following ways:

Cuticular Transpiration : Cuticle is the waxy covering of the epidermis of leaves and green herbaceous stems. Though it is mean to transpiration about 10% of the total transpiration may take place through fine cuticle pores.



Lenticular Transpiration : loss of water vapor through the lenticel of the twigs, branches and fleshy fruits which are made up of loosely about 0.1 % of water. The lenticels are tiny openings in the cork tissue.



Stomata Transpiration : Stomata are minute pores on the epidermis of leaves, or weak green stems, whose opening and closing are controlled by guard cells. About 90 % of water loss from plants takes place through stomata.

Structure of stomata

Stomata are minute pores at elliptical shape consists of two special epidermal cell called guard cells, which are kidney shape in dicotyledon and dumbbell shape in monocotyledon .

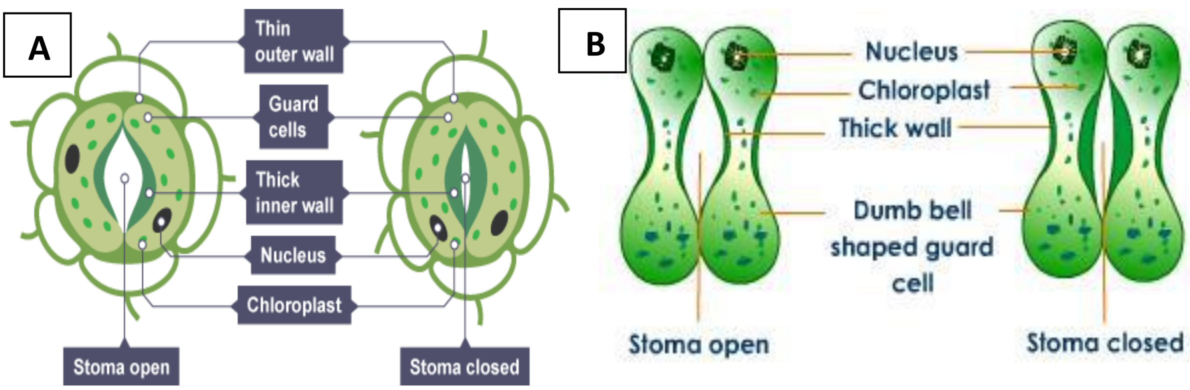


Figure: guard cells in (A) dicotyledon , (B) monocotyledon

The wall of the guard cell surrounding the pore is thicken. Each guard cell has a cytoplasmic, central vacuole, single nucleus and number of chloroplast. The chloroplast of guard cell are capable of very poor photosynthesis, because the absence of RUBISCO (Ribulose-1,5-bisphosphate carboxylase/oxygenase) enzyme. Guard cells are surrounded by modified epidermal cells, known as assistant cells, which supports in the movement of guard cells.

The Size and shape of stoma and guard cell vary from plant to plant. In many gymnosperms and xerophytic plants {plants growing in desert), the stomata are present embedded deeply in the leaves, so that they are not exposed to sunlight directly. This is an adaptation to check excessive transpiration in these plants.

Number of Stomata (Stomatal Frequency):

The number of stomata in the area of leaf varies from plant to plant. Xerophytes possess larger number of stomata than mesophytes. The number of stomata per unit area of leaf is called Stomatal Frequency. Stomata frequency of trees and shrubs is higher than herbs.

The number of stomata on the **upper** surface of leaves is much less in comparison to those found on the **lower** surface.

Plant Number of Stomata/mm²		
	Upper Surface	**Lower Surface**
Monocot		
Wheat	50	40
Barley	70	85
Onion	175	175
Dicot		
Sunflower	120	175
Alfalfa	169	188
Geranium	29	179

Mechanism of transpiration

Mechanism of transpiration

Transpiration occurs in two stages :

(i) Evaporation of water from the cell walls of mesophyll cells into the intercellular spaces.

(ii) Diffusion of this water vapour of the intercellular spaces into the outside atmosphere, through cuticles, lenticels and stomata, when the outside atmosphere is drier.

Opening and closing of stomata (Stomatal movement)

The stomata are easily recognized from the surrounding epidermal cells. The epidermal cells that immediately surround the stomata may be similar to other epidermal cells or may be different and specialized. In the latter case, they are called as assistant cells.

The guard cells differ from other epidermal cells also in containing chloroplasts. Consequent to an increase in the osmotic pressure of the guard cells, osmotic diffusion of water from surrounding epidermal cells and mesophyll cells into guard cells follows. This increase the turgor pressure of the guard cells. The guard cells swell, increase in length and their thickened surfaces and forming a pore and thus the stomata open.

On the other hand, when osmotic diffusion of guard cells decrease, relative to surrounding epidermal and mesophyll cells, water is released back and the guard cells become flaccid. The thickened surfaces of the guard cells come close to each other, thereby closing the stomatal pore and stomata.

Osmotic diffusion of water into guard cells occur when their osmotic pressure increases and water potential decreases related to those of surrounding epidermal and mesophyll cells. The guard cells become flaccid when their osmotic pressure decreases relative to the surrounding cells.

So guard cells control the opening and closing of the stomata.

Role of transpiration:

1. Transpiration helps to "**pull**" the water through the xylem tissues.

2. The water stream moving upwards carries dissolved minerals with it, and helps in distributing these minerals throughout the plant.

3. Transpiration regulates plant temperature by cooling plants in hot environments by 2-3 c˚.

4. By transpiration, water moves upward and as it passes into the cell vacuoles, it makes the cells turgid. This gives form and shape to cells and plant as a whole.

Conditions influencing Transpiration:

I- Internal factors (Plant factors) :

1. Number, size, position and distribution of stomata.

2. The areas of leaves.

3. The structure of leaves (the presence of thick cuticle, where wax reduces the rate of cuticular transpiration).

4. Water status of the plant.

II- External factors:

1. **Sunlight**: on a bright sunny day, the stomata are fully open and the rate of transpiration increased. On a cloudy day, the stomata are partially open and transpiration is reduced. At night, the stomata closes and transpiration is reduced.

2. **Temperature of the Air**: When the temperature is high, the rate of transpiration increases. This is because at higher temperatures water evaporates more than at low temperatures.

3. **Humidity of the Air**: when the air is dry, the rate of transpiration increases. If the air is moist or saturated with water vapour, transpiration is minimized.

4. **Wind or Air Movement**: Transpiration is more rapid or active, when the wind speed is high, and reduced in still air.

5. **Availability of soil water**: Transpiration can be maintained only if the roots absorb water from the soil and compensate the loss of water from the aerial parts.

Adaptations to control Excessive Transpiration

1. Morphological Adaptions:

Since maximum water loss takes place through the leaf surface, the leaf area is reduced in various ways.

a. Leaves may be modified into spines or needles.

b. Leaves may be folded or rolled.

c. Leaves may be shed, as in deciduous trees.

2. Anatomical Adaptations

a. The number of stomata are reduced or remain sunken in pits.

b. A thick waxy cuticle develops on the epidermis.

c. Shrubs & trees develop a water- covering of cork.

d. A multiple epidermis may develop in some leaves.

Theories of Stomatal Movement

Theories of Stomatal Movement

1-Starch- Sugar Hypothesis

This hypothesis based on the increase in sugar concentration (from photosynthesis) in guard-cells and hence endosmosis of water during the day leads to turgidity of guard cells leading to opening of stomata and the reverse decrease in sugar concentration followed by exosmosis leads to closing of the stomata at night.

2-Effect of potassium ions (K+) on stomatal opening and closing

It has been proved that the accumulation of K+ ions in guard cells brings about the opening of stomata and loss of K+ ions from guard cells into assistant cells brings about, the closing of stomata.

3-

During Day Light	During Night/Dark
Accumulation of K^+ ions by the guard cells	Loss of K^+ ions by the guard cells
↓	↓
Increased solute concentration	Decreased solute concentration
↓	↓
Endosmosis of water	Exosmosis of water
↓	↓
Increased turgidity	Decreased turgidity
↓	↓
Stoma opens	Stoma closes

Theory of Photosynthesis in Guard Cells:

Von Mohl (1856) observe that stomata open in light and close in the night. He then proposed that chloroplasts present in the guard cells photosynthesize in the presence of light resulting in the production of carbohydrate due to which osmotic pressure of guard cells increases

Transpiration is a necessary evil

Stomata remain open during day time for the absorption of carbon dioxide and release of oxygen for a very important process of photosynthesis. When the stomata remain open for this important gaseous exchange, escape of water vapour cannot be controlled. Thus loss of water is a wasteful process which cannot be avoided because stomata must remain open to do something more important that is absorption of carbon dioxide during day time for photosynthesis. It is for this reason

that Curtis in 1926 has referred transpiration as a necessary evil

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Plant Nutrition

Growth is the development of a plant as a whole or of a specific organ. Besides the genetic factors, the environmental factors grouped as climatic factors and soil factors influence plant growth. A complete analysis of plants detects large number of elements. But only certain elements are essential.

Each nutrient element do a limiting function in plant. An extremely decreasing or increasing in its content due to a disruption in some processes shows its symptoms on plant organ like vegetative growth, root, flowers, fruit or seeds.

Earlier 17 elements were considered as essential for plant growth.

They are: C Carbon, H Hydrogen, O Oxygen, N Nitrogen, P Phosphorus, K Potassium, Ca Calcium, Mg Magnesium, S Sulphur, Fe Iron, Mn Manganese, Zn Zinc, Cu Copper, Mo Molybdenum, Bo Boron, Ni Nickel, and CI Chlorine.

Recently each of following added to the above list: Na Sodium, Co Cobalt, Va Vanadium, Si Silicon, Se Selenium, Ga Gallium, Al Aluminum and I iodine.

Elemental Composition of Plants: Over 60 different elements have been found in plants including, arsenic, mercury, lead, uranium, and gold. Three essential nutrients carbon (C), hydrogen (H) and oxygen (O_2) are taken up from atmospheric carbon dioxide and water. Others are taken up by plants from the soil.

Nutrient uptake by plants accounts for about 10 percent of total dry weight of crops, the remaining percentage is organic matter. The chemical symbol and the ionic forms in which the essential elements are absorbed by the plants are given in Table

Table: Eseential elements in plants

Elements Required	Function
Carbon	Occurs in the cell walls, sugars manufactured by chlorophyll, as well as chlorophyll itself
Hydrogen	Important in nutrient uptake from roots. Hydrogen is also essential for the formation of sugars and starches and is easily obtained from water
Oxygen	Required to form sugars, starches and cellulose. Oxygen is essential for the process of respiration
	Macronutrients
Nitrogen	Necessary for the formation of amino acids, co-enzymes and chlorophyll
Phosphorus	Sugar, phosphate and ATP (energy) production-flower and fruit production-root growth
Potassium	Hardiness, root growth, and the manufacture of sugar and starch. Protein synthesis also requires high potassium levels
Calcium	Required for cell wall formation
Magnesium	Chlorophyll production, enzyme manufacture
Sulfur	Protein synthesis, water uptake , fruiting and seeding, natural fungicide
	Micronutrients
Boron	Necessary for the formation of cell walls when combined with Calcium
Chlorine	Required for photosynthesis, essential part of cytochromes
Copper	Activates enzymes, necessary for photosynthesis and respiration
Iron	Chlorophyll formation, respiration of sugars to provide growth energy
Manganese	A catalyst in the growth process, formation of oxygen in photosynthesis
Molybdenum	Nitrogen metabolism and fixation
Zinc	Chlorophyll formation, respiration and nitrogen metabolism

SYMPTOMS OF MINERAL DEFICIENCY IN PLANTS

The absence or deficiency (not present in the required amount) of any of the essential elements leads to deficiency symptoms. Some common deficiency symptoms are

Chlorosis - It is the loss of chlorophyll leading to yellowing in leaves. It is caused by the deficiency of elements like K, Mg, N, S, Fe, Mn, Zn and Mo.

Necrosis or death of tissues, particularly leaf tissue is caused by deficiency of K, Ca, Mg **Inhibition of cell division** is caused due to lack or deficiency of N, K, B, S and Mo.

Stunted/Retarded plant growth caused by the deficiency of N, P, K, Zn, Ca

Premature fall of leaves and buds is caused by deficiency of K, P.

Delay in flowering is caused due to deficiency of N, S, Mo.

For diagnosis an element deficiency in plant we depend on:

- Soil analysis.
- Plant analysis
- Agricultural experience.

An element is considered essential if:

a) Required for growth and development.

b) Directly involved in plant metabolism.

c) Required for life cycle completion.

d) No other element can substitute for it.

Classification of essential elements

Essential elements needed for the crop growth are broadly classified:

Based on the relative Quantity that is normally present in Plants

• Macro nutrients (Major Nutrients/primary nutrients): C, H, O, N, P, K, Ca, Mg , S

• Micro Nutrients (Minor Nutrition / secondary elements): Fe, Mn, Zn, Cu, Mo, H, Cl, and Na, Se, Co, V, Ga, Al and I.

Based on their Chemical Nature

• Metals: K, Ca, Mg, Fe, Zn, Mn, Cu, Co and V etc.

• Non-Metals: C, H, O, N, P, S, B, Mo, Cl, Si, etc.

• Cations: NH_4^+, K^+, Ca^{2+}, Fe^{2+}, Mg^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}

• Anions: $N0_3^-$, HPO_4^-, $H_2P0_4^-$, SO_4^{2-}, BO_3^{3-}, MoO_4^{2-}, Cl^-, etc.

Based on General Function

• As a constituent of either organic or inorganic compounds: N, S, P, Ca, H, Fe and Mg.

• As an activator, cofactor in prosthetic group of enzyme systems: K, Mg, Ca, Fe, Zn, Mn, Cu, Mo, Na and C1.

• As a charge carrier in oxidation-reduction reactions-P, S, Fe, Mn, Cu, Mo.

• As an osmosis regulator and for electron chemical equilibrium in cells: K, Na and C1.

Based on the Mobility in Plants

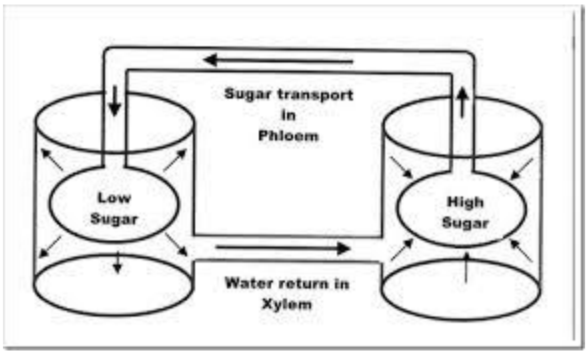
•N, P,K	Highly mobile
•Zn	Moderately mobile
• S, Fe, Cu, Mn, Cl, Mo	Less mobile
• Ca, B	Immobile

Deficiencies of the essential elements result in abnormalities in the affected plants. A specific pattern of abnormalities is characteristic of the deficiency of each element. The nature of the deficiency symptoms often correlates with the function of an element in plant structure or metabolism. Iron, which is not a component of chlorophyll is necessary for chlorophyll formation, and its deficiency results in a striking chlorosis in the young leaves.

Mechanism of Mineral Salt Absorption

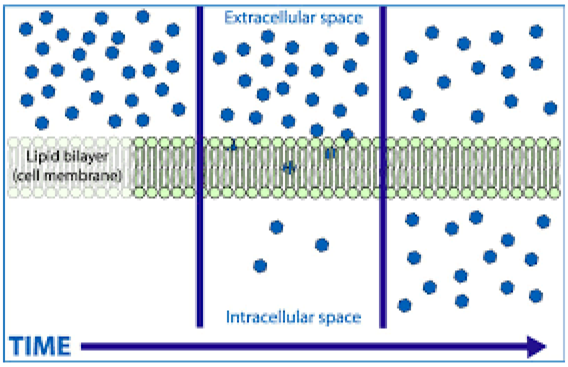
I- Passive uptake: It is the uptake of ions by purely physical processes, which do not require plant energy. Some such mechanisms are:

(I) **Mass Flow:** The ions are taken up by the roots with the mass flow of water, taking place under the influence of transpiration, such as Ca, B and Mo. It is difficult to accept this proposition in the light of our present knowledge.



Mass flow

(II) Diffusion: The ions diffuse through the root surfaces when their concentration in the soil solution is higher than that in the plant sap through simple and facilitated diffusion.



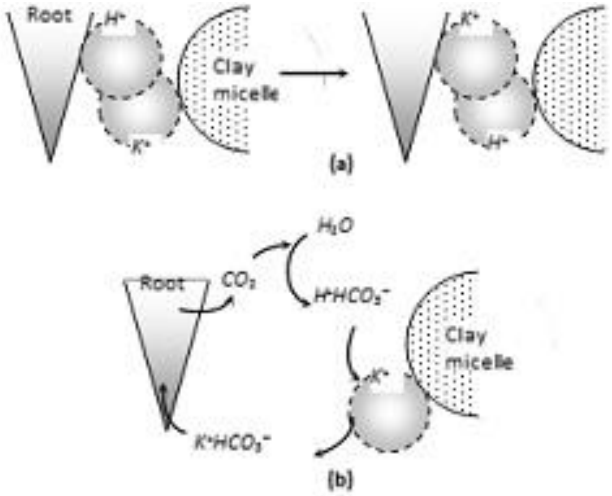
(III)Ion Exchange: anions or cations present within the cells are exchanged with anions or cations of equivalent charge of the external solution. It has been explained by two theories:

1) The contact exchange theory.

2) The carbonic acid exchange theory.

- According to the contact exchange theory: an ion may be absorbed by the plant root without being first dissolved in the soil solution. An ion adsorbed electrostatically to a solid particle, such as a plant root or clay micelle

- In the carbonic acid theory: the soil solution provides the medium for the exchange of ions between the root and the clay micelles. Carbon dioxide released in respiration combines with water to form carbonic acid in the soil solution. Carbonic acid dissociates into H+ and (HCO-) ions. A cation adsorbed on the clay surface may be exchanged with H+ of the solution



Diagrammatic representation of (a) The contact-exchange theory and (b) The carbonic acid exchange theory

Diagrammatic representation of (A) the contact exchange theory and (B) the carbonic acid exchange theory.

(IV) Donnan Equilibrium According to the scientist Donnan this theory suggests that the presence of a concentration of certain 'fixed' or in diffusible ions within the cell would require to be balanced by ions of the other charge. Such as proteins and nucleic acids are present on one side of a membrane, because of their molecular size, proteins do not diffuse in or out of the cells through their membranes, while mineral ions can do so. When excess of protein is present on the inner side of the membrane, it will allow the inward diffusion of cations so that the two charges (of cations and anions) are balanced.

According to this theory the diffusion will continue until an equilibrium called Donnan equilibrium is achieved. At this stage, the ratio of cations to anions on the inner side of the membrane is equal to the ratio of cations and anions on the outer side.

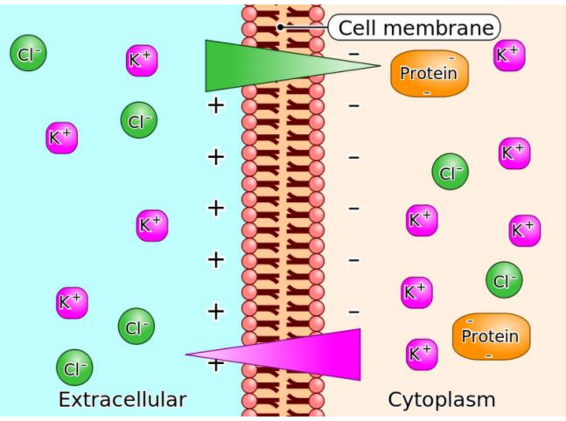


Fig: Effect of Donnan equilibrium in ion distribution

II- Active uptake: Various experiments support that uptake of mineral ions is an active process and a metabolic energy is utilized in the process. Some of the evidences in favor of active uptake are as follows:

(1) Salts or ions may be accumulated inside the cells in concentrations higher than their concentrations outside.

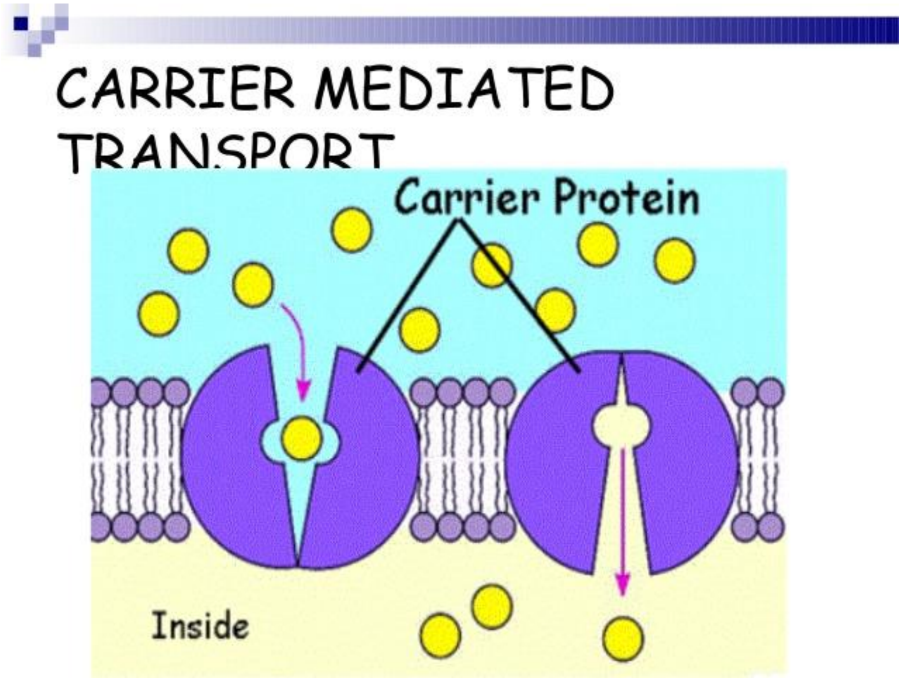
(2) Plant can absorb anions like HPO4 -2 , H2PO4 - , SO4 -2 , NO-3 which they are similar to anion charge of cell wall and plasma membrane.

(3) Like any other physiological process, the rate of ion uptake increases with the increase in temperature in the range of about 10 to 30°C. Freezing temperatures inhibit the ion uptake.

(4) Many metabolic inhibitors such as fluoride and dinitrophenol inhibit ion uptake.

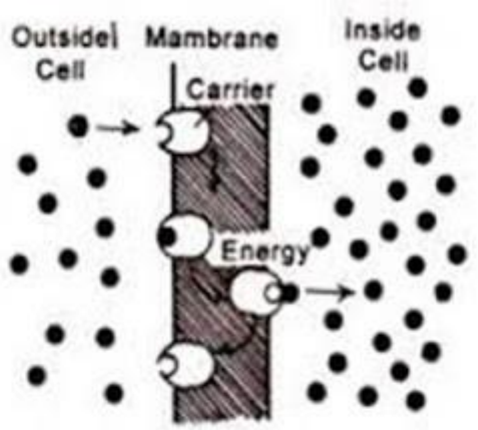
The following mechanisms for active transport have been suggested:

1. Carrier mediated uptake: The carrier was a special compound which transported ions across the cell membrane and released it inside the cell. In addition to ATPase, it is also probable that there is a specific carrier protein for individual or a group of related ions.



2. Anion respiration hypothesis: This hypothesis proposed that the uptake of anion was linked to respiration while that of cation was a passive process, and the cytochromes (of electron transport system) are involved in anion transport.

According to the hypothesis, the cytochrome at the outer surface of the membrane are oxidised (Fe^{3+}) while that on inner side are reduced (Fe^{2+}). At the outer surface, when it undergoes oxidation, it loses one electron and picks up an anion in exchange of electron. The released electron unites with a proton (H+) and oxygen to form water. At inner surface the oxidised iron of the cytochrome is reduced by picking up an electron which has been released by the action of dehydrogenases involved in respiration.



Showing translocation across the membrane by the carrier mechanism.

Fig: Diagrammatic representation of carrier mediated ion transport through the membrane.

3. Electro-chemical gradient hypothesis or Chemi-osmotic hypothesis: According Peter Mitchell (1968), the enzyme ATPase hydrolyses ATP to ADP and Pi, splitting water to H+ and OHat the same time. The membranes excreted H+ outside, because of this, a proton gradient is generated in the membrane and cations enter the cell. Ion transport will occur if an anion is exchanged for a OH- .

Fig: Ion transport coupled to ATPase activity. رسم

Factors Affecting Mineral Uptake

1. Internal factors:

1- Growth: Cell division, elongation and developmental processes promote the absorption of mineral salts, because the metabolic activities in the root create a demand for the nutrients, which influences their uptake.

2- Aging: Young roots are able to take more of minerals than the older suberized and lignified roots.

2. External factors

1-Temperature: In general, an increase in temperature results increase in the absorption of salts up to a certain optimum level.

- At very high temperature the absorption is considerably inhibited. The inhibition might be due to denaturation of proteins which are directly or indirectly involved in mineral salt absorption.

- The change in temperature also affects the process of diffusion. The rate of diffusion depends upon the kinetic energy of diffusing molecules or ions which, in turn, dependent upon temperature.

2- Light: Light has no direct effect, but indirectly by transpiration and photosynthesis, influences salt absorption.

3. Oxygen: The active salt absorption is inhibited by the absence of oxygen.

4. Antagonism: The absorption of one ion is affected by the presence of other ions in the medium. They may either potentiate the effect or retard it. For some ions, it has been observed that the antagonistic effect is because of competition in their uptake. Potassium, rubidium and caesium have been found to compete with one another for the same carrier site, in barley roots. Potassium antagonize sodium and ammonium uptake and calcium is antagonize the uptake of magnesium vice versa.

5. Hydrogen ion concentration (pH): Change in the hydrogen ion concentration (pH) of the soil solution affects the availability of ions to the plants. In general, decrease in the pH of soil solution accelerates the absorption of microelements except the molebdnum.

Figure :Influence of pH on Nutrient Availability

6. Mycorrhiza: Mycorrhizal associations of the fungi with plant roots do the following:

- Increases the absorbing surface for water and minerals.
- These micro-organisms generally increase nutrient availability to roots.
- In some cases they also participate in the solubilization and mobilization of nutrients in the soil.

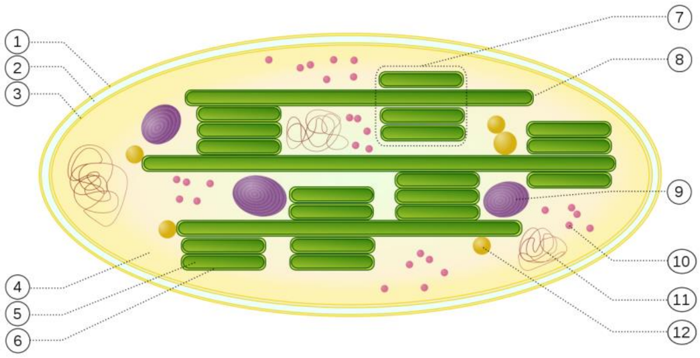
• In a few cases, the mycorrhizal fungi may compete with the plant roots for the nutrients, and thus decreasing the nutrient uptake by the roots.

Photosythesis

Introduction Life on earth would be impossible without photosynthesis. The autotrophic plants synthesize huge amounts of organic food with the help of the light energy available from sun. Carbohydrates produced through photosynthesis constitute the basic raw materials, which directly or indirectly give rise to all the organic components of all plants and animals. The entire humanity depends upon the prepared food of plants. It has been estimated that plants take up 7x1011 tons of CO2 to produce roughly 5 x l011 tons of solid plant material. Approximately 90 percent of the world's photosynthesis is carried out of marine and freshwater algae. Photosynthesis: is a biochemical process by which green plants and some other organisms use sunlight to synthesize foods from carbon dioxide and water in the presence of chlorophyll.

Where photosynthesis occurs?

Plant photosynthesis occurs in leaves and green stems within specialized cell structures called chloroplasts. Within plants most chloroplasts are found in the mesophyll cells of leaves. The chloroplast, an oval-shaped structure, is divided by membranes into many disk-shaped compartments, called thylakoids, arranged vertically in the chloroplast like a stack of plates called a granum (plural, grana); the grana lie suspended in a fluid known as stroma.



Chloroplast ultrastructure:

1. outer membrane
2. intermembrane space
3. inner membrane (1+2+3: envelope)
4. stroma (aqueous fluid)
5. thylakoid lumen (inside of thylakoid)(grana)
6. thylakoid membrane
7. grana
8. Stroma lamella
9. starch
10. ribosome
11. plastidial DNA
12. plastoglobule (drop of lipids)

Chloroplast components.

Hundreds of molecules of chlorophylls, a light-trapping pigment required for photosynthesis are embedded in the membranes of the thylakoids. Additional light trapping pigments, enzymes and other molecules needed for photosynthesis are also located within the thylakoid membranes. The pigments and enzymes are arranged in two types of units, Photosystem I and Photosystem II.

Photosynthesis pigments

1- **Chlorophylls:** There are at least seven types of chlorophylls known: chlorophylls a, b, c, d and e, bacteriochlorphyll and bacterioviridin. Both chlorophyll a and b contain :

- Hydrophilic Mg.

- Porphyrin head.

– Liophilic phytol tail. The molecular formulae of the chlorophylls are given below :

Chlorophyll a : $C_{55}H_{72}O_5N_4Mg$

Chlorophyll b : $C_{55}H_{70}O_6N_4Mg$

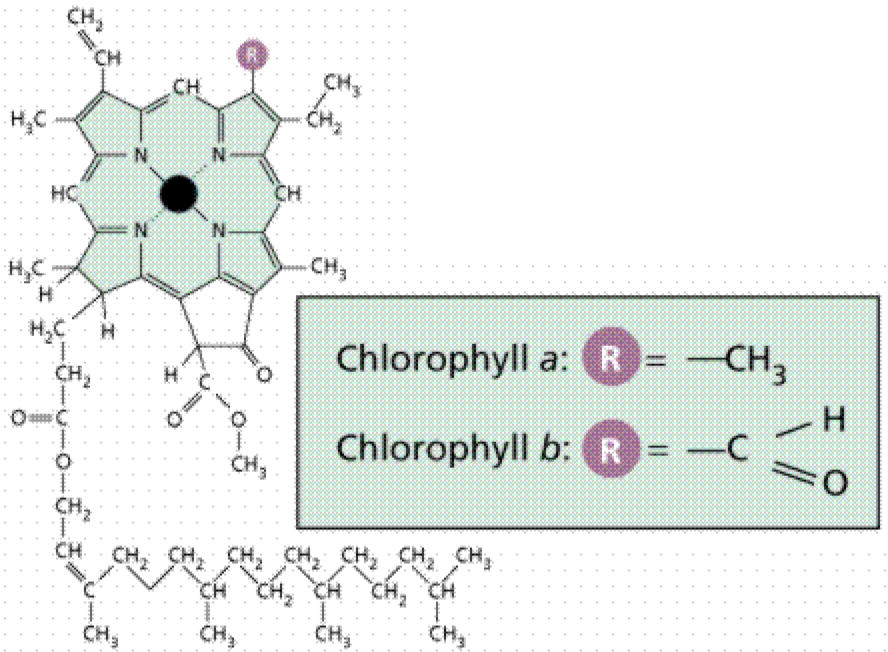


Figure.Structure of chlorophyll a and b.

Chlorophylls a and b are the two most abundant chlorophylls.

Chlorophyll a is found in all the autotrophic plants except the photosynthetic bacteria. Chlorophyll b is a secondary pigment, it is absent in the blue-green, brown and red algae. The other chlorophylls (c, d, e) are found only in algae and in combination with chlorophyll a. Chlorophyll a has two absorption peak occur at 430 nm and 662 nm, while Chlorophyll b absorbing light wavelengths that chlorophyll a does not absorb at 453 nm and 642 nm.

2- Carotenoids: The carotenoids are the main accessory pigments in photosynthesis. They transfer the light energy to chlorophyll for photosynthesis. They occur in bacteria, algae and higher plants. They include orange carotenes and yellow xanthophylls. They absorb wavelengths 400 nm to 500 nm because of which they are orange and yellow in color. Function of carotenoids This methyl substitutes by CHO in chlorophyll b .

They trap light energy and transfer it to the chlorophyll a particularly in algae and to some extent in higher plants. In higher plants this function is performed by lutein of the xanthophylls and β-carotene.

3- Phycobilins: The red algae absorb green light. Since chlorophylls hardly absorb green light it became clear that some other accessory pigment was involved.

A general equation for photosynthesis is: photons

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} \xrightarrow{\text{Light}} \underset{\text{Sugar}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

Oxygen released in photosynthesis comes from water molecules

Photosynthesis stages: Photosynthesis consists of two main stages, a light phase and a dark phase. There are two primary photochemical reactions in the light phase. These reactions are sensitive to light but not temperature. The reactions of the dark phase arc sensitive to temperature but not light.

Figure: The absorption spectrum for photosynthesis pigments and the action spectrum for photosynthesis.

The chloroplast traps light energy and converts it into chemical energy contained in adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide phosphate (NADPH), two molecules used in the second stage of photosynthesis. The phase contains:

Emerso effect

When Emerson exposed green plants to differing wavelengths of light, he noticed that at wavelengths of greater than 680 nm the efficiency of photosynthesis decreased abruptly. When the plants were exposed to short-wavelength light, (less than 680 nm), the efficiency also decreased. Emerson then exposed the plants to both short and long wavelengths at the same time, causing the efficiency to increase greatly. He concluded that there must be two different photosystems involved in photosynthesis, one driven by short-wavelength light and one driven by long-wavelength (PS1 and PS2). They work together to enhance efficiency and convert the light energy to forms that can be absorbed by the plant. This phenomena known Emerson enhancement effect

- Photosystem II (PS II) consists of a pigment complex and electron-acceptor molecules, it oxidizes H2O and produces O2. The electron transport system consists of cytochrome complexes and transports electrons and pumps H+ ions into the thylakoid space and produced ATP.

- Photosystem I (PS I) has a pigment complex and electron-acceptor molecules, it is associated with an enzyme that reduces NADP+ to NADPH. The procedure done as follows:

1- Light energy is trapped in PSII by chlorophyll a (p680) and ejects electrons to a higher energy level.

2- The electrons are received by an electron acceptor.

3-The electrons are passed from the electron acceptor along a series of electron carriers (Plastoquinone to Cytochrome to Plastocyanin) to PSI which is at a lower energy level. The energy lost by the electrons is captured by converting ADP to ATP. (Light energy has been converted to chemical energy)

4- Light energy absorbed by PSI by chlorophyll a (p700) ejects the electron to a higher energy level.

5- The electrons are received by another electron acceptor.

6- The electrons are passed from the electron acceptor along a series of electron carriers (Quinone to Ferredoxin).

7- The electrons which have been removed from the chlorophyll are replaced by pulling in other electrons from a water molecule.

8- The loss of electrons from the water molecule causes it to separate into protons and oxygen gas

(photolysis of water):

$$2H_2O\ 4H^+ \rightarrow 4\ e^- + O_2$$

9- The protons from the water molecule combine with the electrons from the second acceptor and these reduce $NADP^+$ to NADPH. $NADP^+ + 2\ e^- + 2H^+$ NADPH + H^+ ATP

production during photosynthesis is called photophosphorylation.

There are two types of photophosphorelation in light reaction:-

a - The noncyclic photophosphorelation: ATP production combined with travelling electrons from H_2O to final receptor ($NADP^+$). This type uses the two photosystems, PS-I and PS-II.

b- The cyclic photophosphorelation: Sometimes the electrons returns from the ferredoxin and combine to P700 through Cyt.b6. It uses only photosystem I (PS-I).

Figure:. Electrons flow in light reaction photosystems (Z- Scheme)

Importance of light reaction

1-Produce O_2.

2-Produce NADPH.

3-Produce ATP (Photosynthetic phosphorylation).

II-The dark reaction (the light-independent reaction or Calvin Cycle Reactions or Carbon Dioxide Fixation):

Termed the Calvin cycle after the American chemist Melvin Calvin who discovered it, the light-independent reactions use the NADPH and ATP produced in light reaction for producing glucose. These reactions occur in the stroma, and each step is controlled by a different enzyme. With the help of an enzyme, six molecules of carbon dioxide bond to six molecules of RuBP to create six new molecules. Several intermediate steps, which require ATP, NADPH, and additional enzymes, rearrange the position of the carbon, hydrogen, and oxygen atoms in these six molecules, and when the reactions are complete, one new molecule of glucose has been constructed and five molecules of RuBP have been reconstructed. This process occurs repeatedly in each chloroplast as long as carbon dioxide, ATP, and NADPH are available.

The procedure done as follows :

1- CO_2 diffuses into the leaf through the stomata. It then travels into the stroma of the chloroplast.

2- The CO_2 then combines with a 5- carbon molecule named ribulosebisphosphate (RuBP) by RuBP Carboxylase forming an unstable 6-carbon molecule in a process known as carbon fixation.

3- This 6-carbon molecule splits into two 3-carbon molecules called 3- phosphoglycerate (3PG).

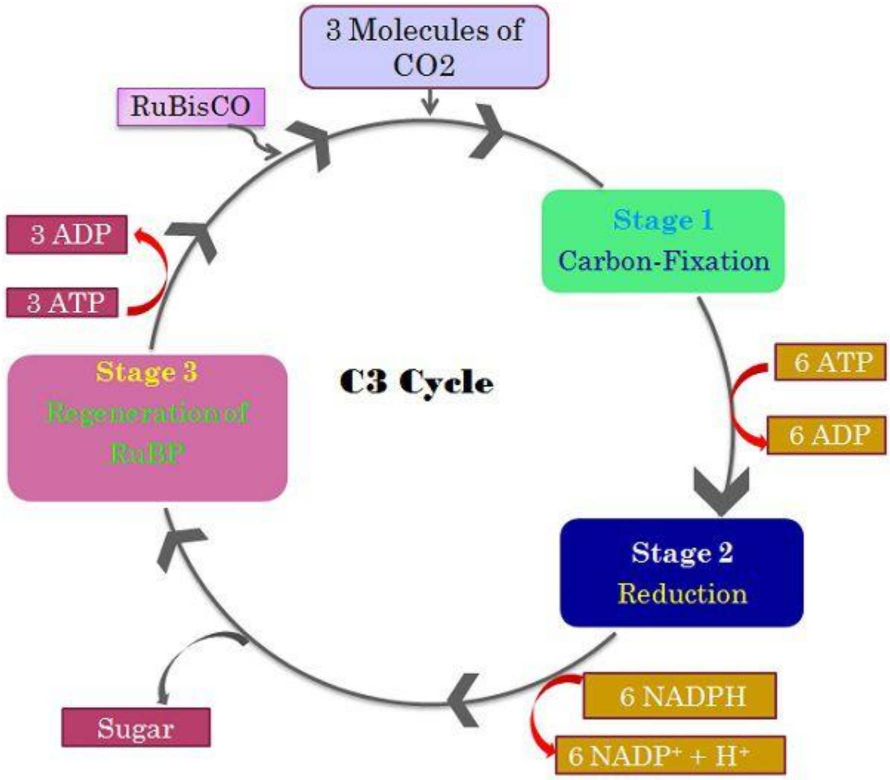
4- 3PG reduced to 1,3-bisphosphoglycerate (BPG) by utilizing the ATP produced in light reactions.

5- BPG then reduced to glyceraldehydes-3- phosphate (G3P) by utilizing NADPH produced in light reactions.

6- RuBP used in CO_2 fixation must be replaced.

7- Every threeturns of Calvin Cycle,five G3P (3-carbon molecule) used to remake three RuBP (a 5-carbon molecule)

Pairs of triose phosphate molecules can combine to produce an intermediate hexose sugar, this can then be polymerised to form lipids, amino acids, sugars and starch.



Importance of Calvin Cycle

1- A method for CO2fixing. Stroma Thylokoid Stroma

2- G3P (glyceraldehyde-3-phosphate) can be converted to many other molecules. The hydrocarbon skeleton of G3P can form : – Fatty acids and glycerol to make plant oils. – Glucose phosphate (simple sugar). – Fructose (which with glucose = sucrose). – Starch and cellulose. – Amino acids. Red

In C3 plants (80% of plants on earth) , the Calvin cycle fixes CO2 directly, the first molecule following CO2 fixation is 3-carbon molecules(3PG) (3- phosphoglycerate).

C4 Plant photosynthesis

To prevent this process, two specialized biochemical additions have been evolved in the plant world: C4 and CAM metabolism.

• In a C3 plant, mesophyll cells contain well-formed chloroplasts, arranged in parallel layers. While in leaf of C4 plants (e.g. corn , sorghum and sugarcane) the mesophyll cells are arranged concentrically around the bundle sheath cells, which they are as well as the mesophyll cells contain chloroplasts.

• C3 plants use RuBP carboxylase to fix CO_2 to RuBP in mesophyll, and the first detected molecule is 3PG, while C4 plants use the enzyme PEP carboxylase (PEPCase) to fix CO_2 to PEP (phosphoenolpyruvate, a C3 molecule), and the product is oxaloacetate (C4 molecule).

• In C4 plants, CO_2 is taken up in mesophyll cells and malate, a reduced form of oxaloacetate, is pumped into the bundlesheath cells, here CO_2 enters Calvin cycle.

• Photorespiration does not occur in C4 leaves because PEP does not combine with O_2, even when stomata are closed, CO_2 is delivered to the Calvin cycle in bundle sheath cells.

• C4 plants have advantage over C3 plants in hot and dry weather because photorespiration does not occur.

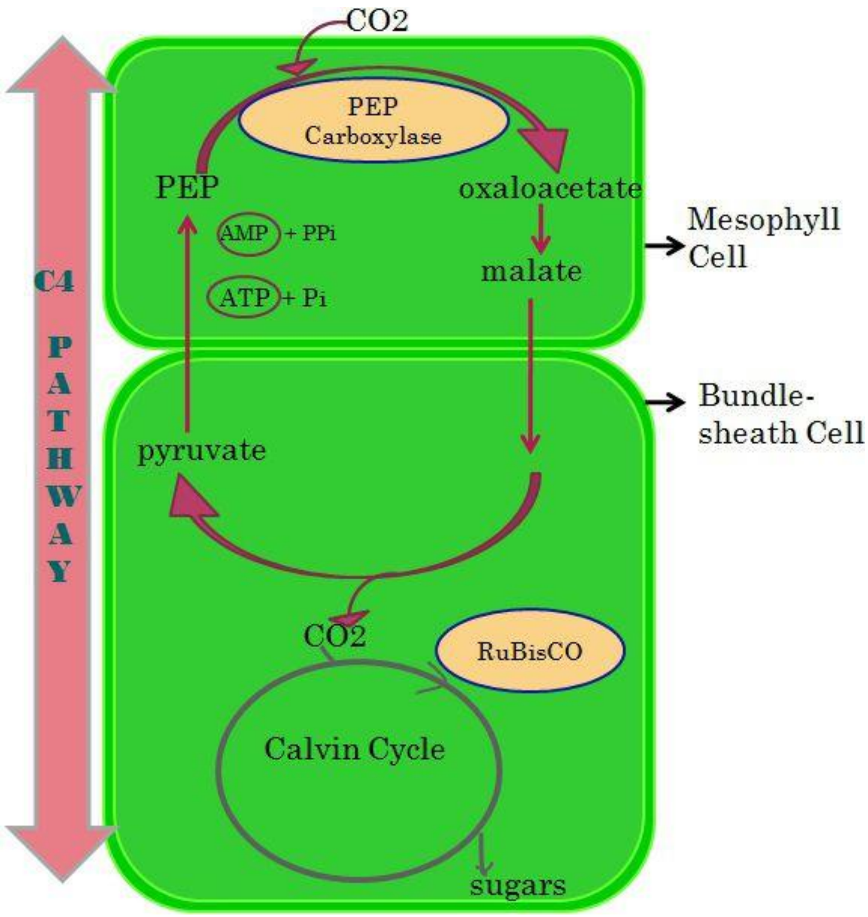


Figure. C4 light independent reaction

CAM (Crassulacean Acid Metabolism)

• CAM plants (found in many succulent desert plants includingyucca , cacti) use a similar process as C4 plants except they let CO2 in at night.

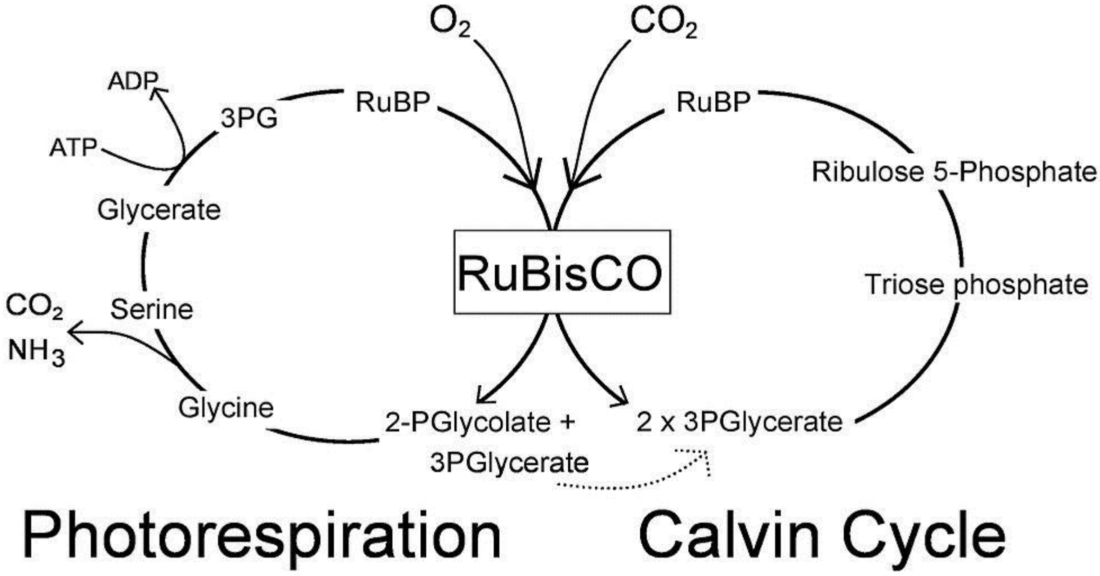
• At night, CAM plants use PEPCase to fix CO2 by forming C4 molecule (malic or aspartic acid)stored in large vacuoles in mesophyll.

• When the sun comes out, they are able to close their stomata and breakdown the malate (malic acid) to keep the internal concentration of CO_2 high enough to prevent photorespiration.

• 4C molecules formed at night is broken down to CO_2 during the day and enters the Calvin cycle.

• Photosynthesis in a CAM plant is minimal, due to limited amount of CO_2 fixed at night, but this does allow CAM plants to live under stressful conditions.

Photorespiration Photorespiration occurs when the CO_2 levels inside a leaf become low, this happens on hot dry days when a plant is forced to close its stomata to prevent excess water loss. If the plant continues to attempt to fix CO_2 when its stomata are closed, the CO_2 will get used up and the O_2 ratio in the leaf will increase relative to CO_2 concentrations. When the CO_2 levels inside the leaf decreased, O_2 starts to combine with RuBP instead of CO_2. The net result of this is that instead of producing 2 PGA (3C molecules), only one molecule of PGA is produced and a toxic (2C molecule) called phosphoglycolateis produced.



Factors affecting the rate of photosynthesis

1- Light: including: Light Intensity – light quality (wave length - light duration.

2- Compensation Point: The ratio between photosynthesis and respiration within a plant, if they"re equal or more respiration takes place the plant cannot grow.

3-Carbon Dioxide (CO2): This can be the most common limiting factor. The atmosphere is only 0.03% CO2.

4-Oxygen (O2) : Oxygen has a competitive inhibitor of carboxylase activity of RuBP and, therefore, inhibits photosynthesis of C3 plants.

5-Temperature: since photosynthesis is a biochemical process with enzymes, temperature will affect this.

6- Water and nutrient elements: Decrease in the water content of the leaves may cause partial or complete closure of stomatal openings, and hence in reduction in the rate of entry of carbon dioxide. A partial drying of the cell walls causes decrease in its permeability to CO_2.

Plant Respiration:

The process of transformation of chemical energy in food into chemical energy (ATP) that cells can use for growth, reproduction, and other life processes. The equation for respiration is the opposite of that for photosynthesis.

$6CO_2 + 12H_2O + \text{Energy (light)} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$ photosynthesis

$C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + \text{Energy (ATP + Heat)}$ Respiration

Nutrients that are commonly used by animal and plant cells in respiration include sugar, amino acids and fatty acids, and a common oxidizing agent (electron acceptor) is molecular oxygen (O_2). The energy stored in ATP can then be used to drive processes requiring energy, including biosynthesis, or transportation of molecules across cell membranes.

- In plants, gases diffuse passively into the plant (through the stomata or directly into the epidermal cells) where they come into contact with the moist cellular membranes and then move in water along diffusion gradients between and within cells.

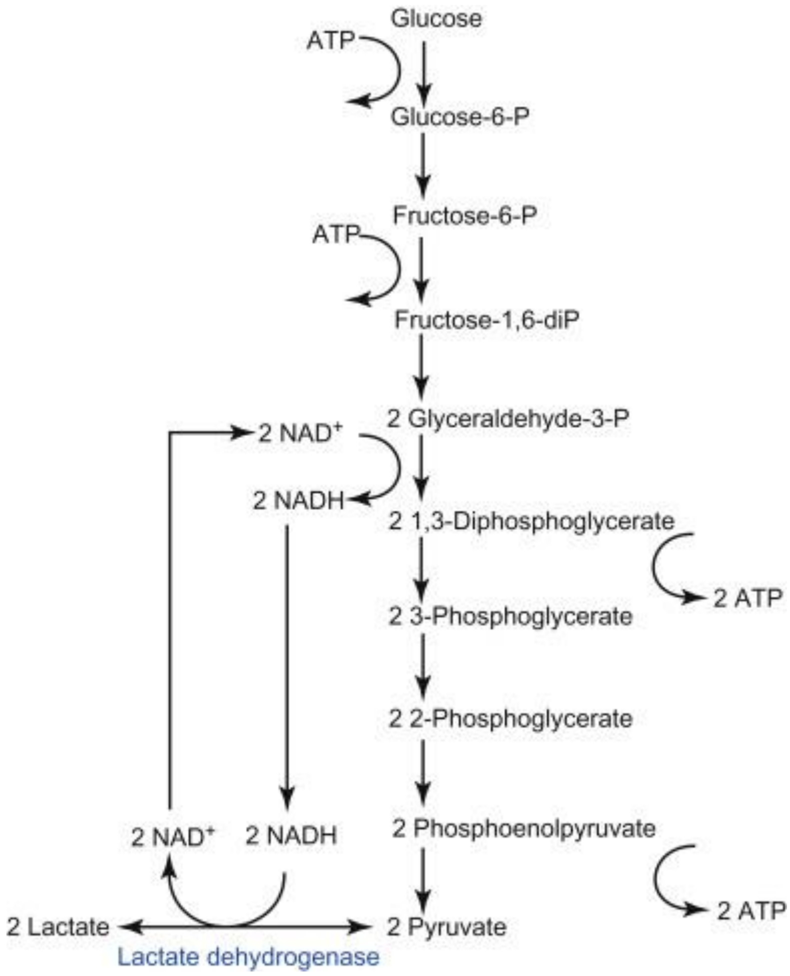
- Glucose is the originating molecule for respiration; other reserve foods are broken down to glucose before undergoing respiratory oxidation. Respiration can be divided into the following stages

1. Glycolysis: is the breakdown of a glucose molecule (6-carbon) into two molecules of pyruvate (3-carbon), it takes place in the cytoplasm of all living cells. If oxygen is present (aerobic respiration), pyruvate is used in the following reactions that take place in the mitochondria: 2. The Krebs cycle (citric acid cycle) occurs in the matrix. 3. Electron transport chain and oxidative phosphorylation occur in the cristae. It includes transfers electrons from NADH and FADH2 to reduce O2 to H2O and generate ATP. If oxygen is not present (anaerobic respiration), pyruvate is used in fermentation. 2. Alcohol fermentation occurs in plant cells.

Glycolysis (glycol=sugar; lysis=breaking) Glycolysis occurs in the cytoplasm of the cell and is present in all living organisms. In this process, glucose undergoes partial oxidation to form two molecules of pyruvic acid. In

plants, this glucose is derived from sucrose, which is the end product of photosynthesis, or from storage carbohydrates. Glycolisis yields 2 ATP and 2 NADH molecules for every one glucose molecule broken down

Utilization of ATP during glycolysis: 1. During the conversion of glucose into glucose 6-phosphate. 2. During the conversion of fructose 6-phosphate to fructose 1, 6-diphosphate. Fermentation Is the process of deriving energy from the oxidation of organic compounds, such as carbohydrates, using an endogenous electron acceptor, which is usually an organic compound. This is in contrast to cellular respiration, where electrons are donated to an exogenous electron acceptor, such as oxygen, via an electron transport chain. Fermentation is less efficient at using the energy from glucose since only 2 ATP are produced per glucose, compared to the 38 ATP per glucose produced by aerobic respiration. This is because the waste products of fermentation still contain plenty of energy



Glycolysis

Aerobic Respiration

The Link Reaction

Pyruvate, the final product of glycolysis is transported from the cytoplasm into the mitochondria. Before the citric acid cycle can begin, pyruvate must be converted to acetyl Coenzyme A (acetyl CoA), which links glycolysis to the citric acid cycle. This step is carried out by a multienzyme complex that catalyses three reactions as shown in figure 9.4. During this process, two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid (produced from one glucose molecule during glycolysis).The acetyl CoA then enter a cyclic pathway, tricarboxylic acid cycle, more commonly called as Krebs‟ cycle after the scientist Hans Krebs who first explained it.

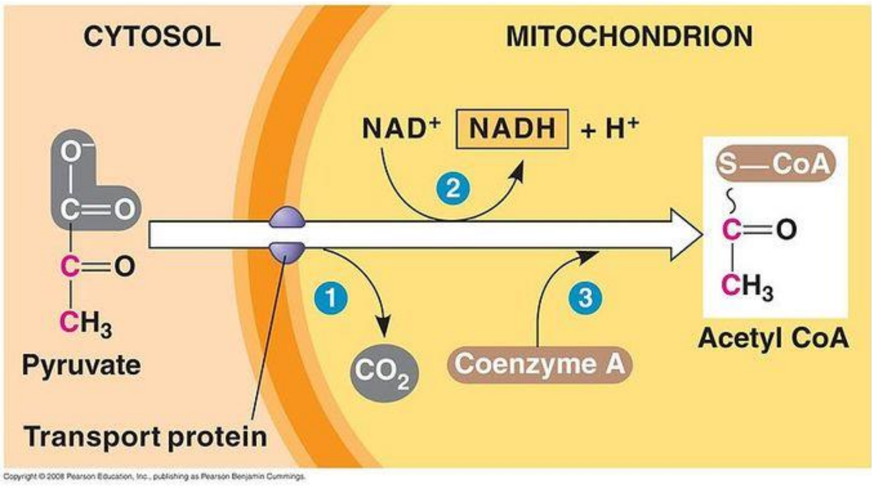


Figure: Preparing pyruvic acid to citric acid cycle Tricarboxylic Acid Cycle (TCA cycle or Citric Acid Cycle or Krebs` cycle) – Krebs` cycle completes the breakdown of glucose.

– Takes the pyruvate (3-carbons) and breaks it down, the carbon and oxygen atoms end up in CO2 and H2O

– Hydrogen and electrons are stripped and loaded onto NAD+ and FAD to produce NADH and FADH2

Steps of citic acid cycle (Krebs` cycle**).**

Step 1 -The condensation of acetyl group with oxaloacetic acid (OAA) and water to yield citric acid. The reaction is catalysed by the enzyme citrate synthase and a molecule of CoA is released. Citrate is then isomerised to isocitrate.

Step 2 -This six carbon compound then undergoes decarboxylation (C02 is removed) and oxidation (hydrogen is removed) to form a five carbon compound (a-ketoglutaric acid). The hydrogen is accepted by NAD+ and forms NADH+ .

Step 3 -The five carbon compound undergoes decarboxylation and oxidation again to form a four carbon compound succinyl CoA). The hydrogen is accepted by NAD+ and forms NADH +

Step 4 -The four carbon compound (succinyl-CoA) will undergoes substrate-level phosphorylation and during this reaction it produces ATP.

Oxidation also occurs twice (2 hydrogens are removed). The one hydrogen is accepted by NAD+ and forms NADH +. The other is accepted by FAD and forms F ADH2 . The four carbon compound is then ready to accept a new acetyl group and the cycle is repeated

Step5- Succinyl 0CoA converts to succinate(4C)

Step6- Succinate coverts to fumarate(4C) and $FADH_2$

Step7- Fumarate (4C)converts to malic acid in the presence H_2O

Step8- Malic acid converts to oxaloacetic acid (4C) which ready accept a new acetyl group and the cycle repeated

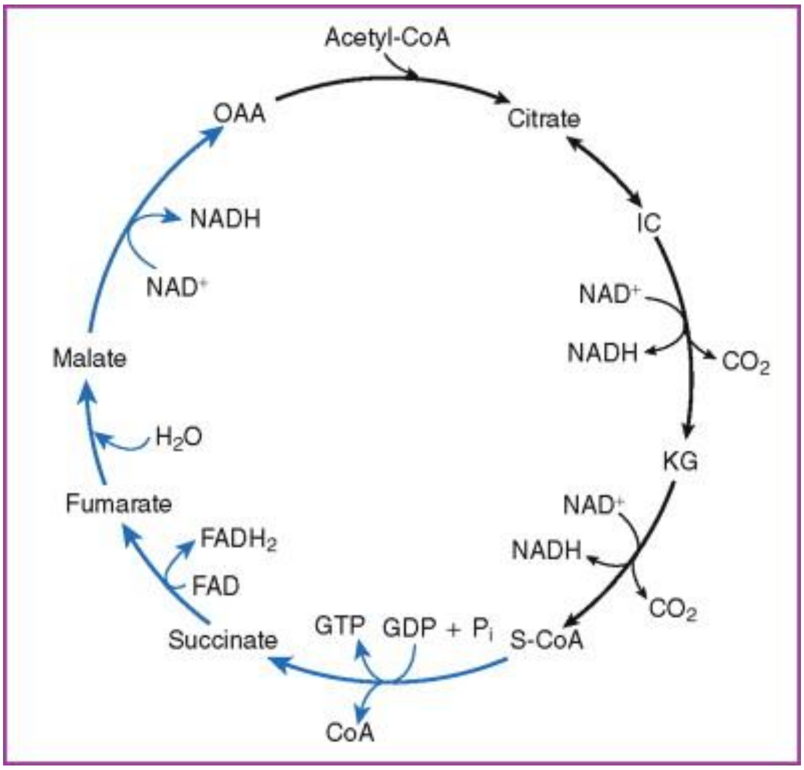


Fig: Steps of citric cycle

Electron Transport Chain (ETC) or Electron Transport Phosphorylation (Chemiosmosis)

The goal of ETC is to break down NADH and FADH2, pumping H+ into the outer compartment of the mitochondria, which creates a gradient which is used to produce ATP.

Electron transport is the most complex and productive pathway of cellular respiration. During aerobic respiration, the ETC produces 34 of the 38 ATP molecules obtained from every molecule of glucose, these ATP comes from a series of oxidation-reduction (redox) reactions between molecules embedded in the membrane of mitochondria. After the Krebs cycle is completed, oxygen enters the respiration pathway as the electron acceptor at the end of the electron transport chain.

It is easiest to understand how electron transport works by divide it into three main events:

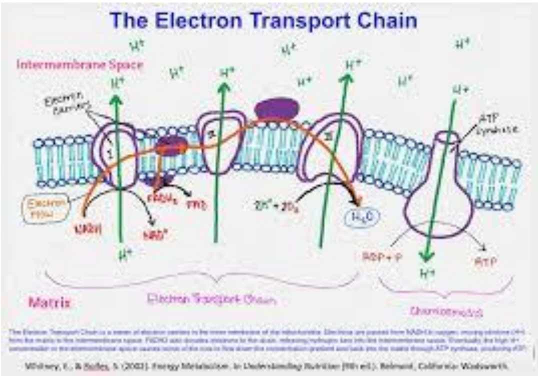
I. Oxidation Reduction Reactions

During glycolysis, synthesis of acetyl-CoA and Kreb's cycles the electron carriers NAD+ and FADH are reduced to form NADH and FADH2 respectively, when NAD+ and FADH are reduced, this means that they accept and carry electrons and hydrogen ions (H+) potential energy that can be used later in cellular respiration. In the electron transport chain, these electron carriers are oxidized, transferring their electrons to the carrier molecules embedded in the ETC membrane. The electrons are then passed from one carrier molecule to another in a series of oxidation-reduction reactions, and finally, in aerobic respiration, to the final electron acceptor, oxygen,

The transport chain often is likened to a series of magnets, each stronger than the last, which pull electrons from one weaker carrier and release it to the next stronger one. The last acceptor in the line is oxygen, an atom of which accepts two energy-depleted electrons and two hydrogen ions (protons) and forms a molecule of water.

2-Creation of Hydrogen Ion Gradient

The energy from each electron being passed down the chain is used to pump a proton (H+) through each carrier molecule, from one side of the membrane to the other. This creates a proton gradient, a type of concentration gradient (difference in concentration of a substance between two sides of a membrane), and gradients are potential energy available for cellular work.



Electron transport chain

3-Phosphorylation of ADP

The H+ on the side of the membrane in which they are most concentrated will eventually flow back across the membrane, down the electrochemical proton gradient through an enzyme called ATP synthase. As each H+ move back across the membrane, ATP synthase phosphorylates adenosine diphosphate (ADP) to make the high energy molecule ATP, which can be used for many different energy-requiring reactions throughout the cell.

Fig:

Aerobic Respiration ATP Production

Step in Respiration	Takes Place in the…	Result
Glycolysis	Cytoplasm	2ATP + NADH
Krebs cycle	Mitochondrial Matrix	2ATP + NADH + FADH2
Electron transport chain and ATP synthesis	In and across the mitochondrial membrane	34 ATP

Net Result: 38 ATP

Not all C respired to CO_2 , therefore there is intermediates of respiration branch off:

♣ amino acids

♣ pentoses for cell wall structure

♣ nucleotides

♣ porphyrin biosynthesis

♣ fatty acid synthesis

♣ lignin precursors

♣ precursors for carotenoid synthesis, hormones

Factors affecting respiration rate

1-Temperature: In the temperature range between 0° and 45C°, a rise in temperature causes a marked increase in the rate of respiration. The respiration rate increases two or three times for every rise of 10°C. The optimum temperature of respiration is near about 30C°.

2-Light: increasing in light due to:

• Increasing temperature degree, followed by increasing respiration.

• Opened stomata and increasing gas exchange.

• Increasing photosynthesis and as a result increasing respiration. (Shaded leaves respire slower than lighted leaves).

3-Oxygen Concentration of the Atmosphere: Oxygen is absolutely essential for the aerobic type of respiration. Considerable changes in the concentration of oxygen in experiment have been found to be ineffective in increasing or decreasing the rate of respiration. (Oxygen had no effect until $O_2 < 1\%$).

4-Carbon Dioxide Concentration: The concentration of CO_2 in atmosphere is almost constant and is, therefore, not likely to affect the respiration rate of the plants to any considerable extent, but high concentration of carbon dioxide does not favor respiration. This is why fruits are stored in Controlled Atmosphere Storage (lower O_2 (2% -3%), raise CO_2 (5% 10%) and temperature typically about (-1 to -0.5C°), due to slows down respiration, while high CO_2 also inhibits ethylene synthesis. High CO_2 concentration inhibits all those activities of the plant which require energy, e.g., the absorption of water and minerals salts, growth of roots and germination of seeds etc.

5-Water: In the case of a well-hydrated plant the rate of respiration is not likely to be affected by slight changes in the content of water. Shortage of water increases the rate of respiration. It is believed that in wilted tissues the accumulated starch gets converted into sugars and, therefore, an increase in the respiration rate takes places. Very low water content, such as in dry seeds, is responsible for very week rates of respiration. Water is absolutely essential for the hydrolysis of reserve carbohydrates into soluble sugars which are absolutely essential in respiration. The respiratory enzymes also need water for their action.

6-Injury: Whenever a plant tissue is wounded the sugar content of the wounded portion is suddenly increased. This increase in the sugar content is believed to be responsible for the observed temporary increase in the respiration rate.

7 -Effect of Certain Chemical Compounds on Respiration : Certain enzymatic inhibitors like cyanides, azides, carbon monoxide, iodoacetate, reduce the rate of respiration even if they are present in very low concentration.

8-Plant age and organ type: Root tips, divisions' buds, growing fruit and meristematic regions in general have higher respiration rates, because they are relatively rich in protoplasm, compared to older tissues in which the proportion of cell walls and the vacuoles is greater, therefore in vegetative tissues respiration

Plant Hormones

What is a plant hormone?

Plant hormones (phytohormones or plant growth substances): are a group of naturally occurring, organic chemical substances which influence physiological processes at low concentrations. A processes like growth, differentiation and development.

Characteristics of plant hormones:

- Synthesized by the plant.

- Active in low concentration($< 10^{-6}$ M)

-Promote or inhibit growth and development responses

-Often show a separation of the sit of production and the site of the action

- They are produced only when needed, they are not stored prior to requirement

-Hormones usually causes long term effects like change in behavior ,growth, etc.

-Hormones are low molecular weight and thy diffuse readily

Planrs have no specialized organs for hormone synthesis an secretion .Leave, stem tips, root tips ,flowers. seeds and fruits all produce hormones.

Major plant hormones are: Auxins, gibberellins, cytokinins, abscisic acid, and ethylene are the best known plant hormones.

Recently brassinolides, jasmolates (jasmonic acid), and salicylic acid have been shown to have hormonal function

1. Auxins

The term auxin is derived from the Greek word auxein which means to grow. Compounds are generally considered auxins if they can be characterized by their ability to induce cell elongation in stems.

An auxin, indole-3- acetic acid (IAA), was the first plant hormone identified. It is manufactured primarily by active young tissues such as the shoot tips (in leaf primordia and young leaves), in embryos, and in parts of developing flowers and seeds. Its transport Plant from cell to cell through the parenchyma surrounding the vascular tissues requires the spending of ATP energy. IAA moves in one direction only (the movement is polar). Downward movement in shoots is said to be basipetal movement, and in roots it is acropetal. Biosynthesis of Auxin IAA is chemically similar to the amino acid tryptophan from which IAA is derived.

Naturally Occurring Auxins

The most important auxin found in plants is indole-3-acetic acid (IAA). IAA is comprised of an indole ring linked to acetic acid .

Fig:IAA

Synthetics with Auxin

Activity There are a variety of substances that are not known to occur in plants that have auxin activity. These include indolebutyric acid (IBA), naphthalene acetic acid (NAA), 2,4- dichloro-phenoxyacetic acid (2,4-D), and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)

Fig: NAA

Some of Auxin Functions:

Auxins alone or in combination with other hormones are responsible for many aspects of plant growth.

1. Activates cellular elongation by increasing the plasticity of the cell wall.

2. Stimulates cell division in the vascular cambium thus promoting growth in stem diameter.

3. Activates the differentiation of vascular tissue in the shoot apex and in calluses, initiates division of the vascular cambium in the spring, promotes growth of vascular tissue in healing of wounds.

4. Stimulates root initiation on stem cuttings and lateral root development in tissue culture.

5. The auxin supply from the apical bud suppresses growth of lateral buds (apical dominance). 6. Delays leaf senescence.

7. Can inhibit or promote (via ethylene stimulation) leaf and fruit abscission (lowered production of auxin in the leaf is correlated with formation of the abscission layer).

8. Inhibits most flowering (but promotes flowering of pineapples).

9. Can induce fruit setting and growth in some plants (from auxin produced by the developing seeds).

10. Delays fruit ripening.

11. Stimulates growth of flower parts, for example seedless tomatoes, cucumbers and eggplants result from spraying plants with synthetic auxins (develop fruits without being fertilized).

12. Promotes femaleness in dioecious flowers.

13. Stimulates the production of ethylene at high concentrations.

14. Tropic responses - such as gravotropism (response to gravity) and phototropism (response to light).

2- Gibberellins

All gibberellins are acidic compounds and are therefore also called gibberellic acids (GA). Gibberellins are widespread and present in flowering (angiosperms) and non-flowering (gymnosperms) plants as well as ferns. They have also been isolated from lower plants such as mosses and algae. The gibberellins are especially abundant in seeds and young shoots. The gibberellins are carried by the xylem and phloem.

Figure 10.2 Structure of Gibberellic acid (GA3)

Some functions of gibberellins:

1. Stimulate stem elongation by stimulating cell division and elongation.

2. Stimulates bolting/flowering in response to long days.

3. Breaks seed dormancy in some plants which require stratification or light to induce germination.

4. Stimulates enzyme production (α-amylase) in germinating cereal grains for mobilization of seed reserves.

5. Induces maleness in dioecious flowers (sex expression).

6. Can cause parthenocarpic (seedless) fruit development.

7. Can delay senescence in leaves and citrus fruits.

3-Cytokinins

Cytokinins are compounds with a structure similar to adenine which promote cell division. The most common form of naturally occurring cytokinin in plants today is called zeatin which was isolated from corn (Zea mays). Cytokinins have been found in all higher plants as well as mosses, fungi, bacteria. Today there are more than 200 natural and synthetic cytokinins combined.

Cytokinins are found in sites of active cell division in plants, for example, in root tips, developing seeds and fruits, and young leaves.

Structure of zeatin and kinetin

Biosynthesis and Metabolism of Cytokinins

Cytokinin is generally found in higher concentrations in meristematic regions and growing tissues. They are believed to be synthesized in the roots and translocated via the xylem to shoots. Cytokinin biosynthesis happens through the biochemical modification of adenine.

Degradation of cytokinins occurs largely due to the enzyme cytokinin oxidase. This enzyme removes the side chain and releases adenine.

Some of Cytokinins Functions:

The response of cytokinins are vary depending on the type of cytokinin and plant species.

1. Stimulates cell division.

2. Stimulates morphogenesis (shoot initiation/bud formation) in tissue culture.

3. Stimulates the growth of lateral buds (release of apical dominance).

4. Stimulates leaf expansion resulting from cell enlargement.

5. May enhance stomatal opening in some species.

6. Promotes the conversion of etioplasts into chloroplasts via stimulation of chlorophyll synthesis.

7. Retard the aging of flowers and leaves. (Cytokinin sprays are used to keep cut flowers fresh)ure of Zeatin and Kinetin

4-Abscisic Acid

Nature of Abscisic Acid It is synthesized in plastids from carotenoids and diffuses in all directions through vascular tissues and parenchyma. Its principal effect is inhibition of cell growth.

ABA increases in developing seeds and promotes dormancy. If a leaf suffers water stress, ABA amounts increase immediately, causing the stomata to close.

Figure Structure of abscisic acid

Some of Abscisic Acid Functions:

1-Stimulates the closure of stomata (water stress increased ABA synthesis).

2-Inhibits shoot growth but will not have as much effect on roots (it may promote growth of roots).

3-Induces seeds to synthesize storage proteins.

4-Inhibits the effect of gibberellins on stimulating synthesis of α-amylase.

5-Has some effect on induction and maintenance of dormancy.

6-Induces gene transcription especially for proteinase inhibitors in response to wounding which may explain an apparent role in pathogen defense.

5-Ethylene

In 1935, Crocker proposed that ethylene was the plant hormone responsible for fruit ripening as well as senescence of vegetative tissues.

Figure :Structure of Ethylene

Nature of Ethylene

Ethylene, unlike the rest of the plant hormone compounds is a gaseous hormone, and has the simplest structure. It is produced in all higher plants, appears in most plant tissues in large amounts when they are stressed, and is usually associated with fruit ripening. Biosynthesis Ethylene is produced from methionine (one of the protein amino acids) in all tissues. Production of ethylene varies with the type of tissue, the plant species, and also the stage of development. Large amounts ordinarily are produced by roots, senescing flowers, ripening fruits, and the apical meristem of shoots.

Some of Ethylene Functions Ethylene is known to affect the following plant processes .

1. Stimulates the release of dormancy, and seed germination.

2. Stimulates shoot and root growth and differentiation.

3. May have a role in adventitious root formation, and root hair development, and root nodulation.

4. Stimulates leaf and fruit abscission.

5. Induction of femaleness in dioecious flowers (monocious plants).

6. Stimulates flower opening.

7. Stimulates flower and leaf senescence.

8. Stimulates fruit ripening.

9. Epinasty : Downward bending of leaves - common response to flooding or waterlogged soils.

Plant senescence

Senescence is the final phase of the development of an organism. It involves cellular breakdown and death. It occurs when catabolism exceeds anabolism. Senescence is a genetically controlled process. The genes which express during senescence are termed senescence associated genes.

Types of plant senescence

1. Whole plant senescence: Annuals and biennials begin to senesce in their entirety when growth reaches flowering and fruiting, like in wheat, rice and mustard, also monocarpic plants which flowering and fruiting once in there live such as bamboo and the century plant (Agave).

2. Shoot senescence: In some perennial herbs if the shoot dies and the plant persists as an underground part, like in banana and gladiolas.

3. Synchronous or Simutaneous' senescence: In deciduous trees like acer and maple where all the leaves senesce and die at the same time in fall.

4. Sequential senescence: In other perennials, where the plant continues to grow, the older leaves at the base tend to senesce and die progressively, like in case of evergreen trees.

Biological Important of Senescence

1. During ripening of fruits and seeds in annuals, there is a considerable breakdown of proteins into amino acids in leaves from where they are exported to the developing seeds to be stored as reserve material.

2. Similar export of reserve material occurs during the synchronous senescence of the leaves in perennials. Sequential senescence of basal leaves of shoot also saving carbohydrates in basal leaves where are heavily shaded and are only concerned with catabolic process of respiration.

3. The plant escapes transpiration under unfavorable conditions, in synchronous type of leaf fall in deciduous plants.

4. The leaves are a source of recycling of nutrients through the soil.

Mechanism of Senescence

Senescence initiation results from the exhaustion of nutrients from leaves and other tissues as they are transported to the developing seeds and it can be delayed by preventing flowering, fruiting and seed setting. Since prevention of flowering delays senescence, but does not prevent it, and the process is more complex interactions than the simple mobilization of nutrients within a plant.

Whole Plant Senescence

There are evidences to show a correlation between seed formation and senescence. It seems that the carbohydrates and proteins of leaves break into sugars and amino acids for mobilizing them as reserves of the seeds, tubers rhizomes, etc. Their transport is supposed to be mediated by auxins. Senescence of plants initiated as a result of imbalance of growth hormones and nutrients. The possible cause of senescence can be summarized as follows:

1. Competition for nutrients. 2. Production of inhibitors by flowers. 3. Altered hormonal level resulting in lack of gene activity and enzyme synthesis.

Most of the works on the mechanism of senescence in plants have been carried on in attached and detached leaves as well as on the flowers of Ipomoea tricolor, which senesce within 24 hours only. Sequential leaf senescence: The senescence of leaves is seen to be associated with the following changes:

1. Yellowing of leaves due to the breakdown of chlorophyll.
2. Breakdown of the membrane of grana.
3. Degeneration of endoplasmic reticulum.

4. Gradual disappearance of the ribosomes.

5. The mitochondria degenerate later during senescence.

6. Gradual decrease in RNA content.

7. Gradual decrease in protein content due to activity of proteolytic enzymes.

8. The amount of amino acids also decreases since they are exported out of the leaves to other parts of the plant e.g. young leaves, seeds, fruits, etc.

Synchronous leaf senescence

In autumn in temperate climate the breakdown of the chloroplasts is the first cytological event during senescence leading to chlorosis. The protein content of the chloroplasts is destroyed. A number of specific genes which are meant for senescence become active and synthesizes many hydrolytic enzymes such as chlorophyll-degrading enzymes, lipases, proteases, nucleases, etc. Synchronous leaf senescence is controlled by environmental factors since the deciduous trees lose their leaves in a particular season e.g. in short days which is believed to be through its effect on decreasing the amount of endogenous hormones like auxins, gibberellins. This type of senescence has also been found to be correlated with export of nutrients from the leaves.

Senescence of detached leaves

There is a considerable fall in RNA and protein synthesis. Though the amino acids are available due to lack of export to the outside, protein cannot be synthesized. Kinetin and gibberellins delay senescence of the detached leaves perhaps by increasing the synthesis of RNA and protein. Senescence of detached leaves can also be delayed if they are allowed to form roots, which perhaps provide the kinetin. The growth inhibitors ABA and ethylene are known to accelerate senescence. Senescence of Flowers Under natural conditions, morning glory Ipomoea tricolor buds open at 5 or 6 O'clock in the morning and remain open until 3 p.m. of the same day. At this time the corolla starts to curl up and changes its color from blue to purple. By the next morning the corolla is completely incurled after which, it abscises. The levels of protein, RNA and DNA fall dramatically in the corolla during development, and the breakdown of nucleic acids coincides with a sharp increase in nuclease RNase and DNase activity (Figure 13.2). During the dying process, a sharp increase in the rate of C_2H_4 evolution occurs.

Senescence of a Cell

Programmed cell death (PCD) is senescence at the cellular level. PCD is very effective in protecting the leaves from pathogens. There is a quick breakdown and death of the cells to cause necrosis which helps in preventing the spread of the disease to the rest of the leaf.